Teague, Kenneth

From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:56 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Attachments: Isolated Wetlands SWG-2013-00982 Trendmaker Homes.pdf

Importance: High

Have we responded to these?

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:13 PM
To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

NOTE: I will be out of the office from 8 Oct thru 20 Oct any questions need to be send to Mr. John Davidson.

Folks;

The purpose of this e-mail is to begin the coordination required for SWG draft non-jurisdictional determination for file SWG-2013-00982; for 51 isolated wetland polygons. This e-mail initiates the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations. NOTE: as of the date of this coordination much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

This approximate 370 acre project area is located east of Ellington Field in League City area of Harris County, Texas. The majority of the site has been landcleared and some detention basins have been constructed. This includes an appx 30 acre tract, located south of the pipeline easement that has not been landcleared. This small portion of the site has a mix of tallow dominated areas and open herbaceous seasonal prairie and has appx. 6 wetland polygons that total an appx 1.8 acres. This entire project area historically contained mostly upland prairie with a mix of seasonal depressional wetlands (some of which were dominated with tallow trees). It has been and continues to have portions being used for graze land. The source of hydrology for the wetlands on the site is precipitation. The wetland are seasonal and depressional. The soils are mapped as clay loams and clays; thus affecting lateral movement of shallow subsurface hydrology.

Since the majority of the site has been impacted by the mechanized land-clearing much of the extents of the wetlands were based upon off-site information in conjunction with four separate field visits conducted by the Corps. (NOTEWORTHY: a previous field visit was conducted by the Corps and EPA {Jim Herrington} to investigate a purported unauthorized activity which was found to not be an unauthorized activity.) The appx. wetland polygons and sizes varied from appx. 0.02 acre to greater than appx. 7 acres (noting greater than 80% are re less than an acre in size); with an estimated aggregate total of appx. 49 acres. The distance to the nearest water of the U.S. (a RPW of Horsepen Bayou) varied from appx. 0.4 mile to greater than 1.3 miles. The appx. distances to the nearest TNW (Armand Bayou) would be appx. 1.3 miles and the furthest would be appx. 2.2 miles. The entire site was examined and based on site information and off-site information there were not any confined surface hydrologic connections nor any shallow subsurface hydrologic connections (based on sampling) detected. All of these appx. 51 wetlands are located outside the anticipated high flow (above the 100-year flood plain of any water of the U.S.). If there were ever to occur any "fill and spill" that might provide hydrology to any waters of the U.S., it would have to be through overland sheet flow, and it would be for extremely brief and episodically events that would occur in extreme above normal circumstances/conditions.

Historically, there have been concerns expressed regarding the fact that recent scientific reports revealed that isolated (as per federal regulations) depressional seasonal wetlands similar to these, provide sinks that fixate N and P and/or effect the water budget; to address this concern it is SWG position that there are numerous other factors that also play into these determinations. Therefore, based on the fact that these geographically isolated wetland that are not "inseparably bound-up" to the nearest TNW, it would be purely speculative to state that the destruction of these wetlands would have more than speculative or insubstantial effect upon the chemical, physical and/or biological integrity of the nearest TNW located greater than 1 mile away.

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

These wetlands (as identified per the manual) are located outside any anticipated high flow (e.g. 100-yr floodplain) of any waters of the U.S., are surrounded by uplands, are not tidal, and are not located in an ecological landscape position that would be utilized for any known species in the geo-region that would require both the wetland and the water body to fulfill their life cycle requirements. These wetlands are located greater than a mile away from the nearest water body. There are not any surface hydrologic connections to any waters of the U.S., these wetlands are not located in a geomorphic position that is inseparably bound to any water of the U.S. nor is there any known biological species in this geo-region that requires both the wetland in review and the nearest TNW to full life cycle requirements.

Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

In conclusion, the Corps has verified that the majority of the site is uplands and there are some pockets of depressional seasonal wetlands on the tract by using on-site and off-site information per the appropriate manual. The wetlands are located in an "isolated" (as defined by federal regulation: 33 CFR 330.2 Definitions:(e) Isolated waters means those non-tidal waters of the U.S. that are:(1) Not part of a surface tributary system to interstate or navigable waters of the US; and (2) Not adjacent to such tributary waterbodies). There is no known nexus to interstate commerce associated with any of them. As such, it is the Corps draft determination that these wetlands would not be subject to federal jurisdiction under Section 404 of the Clean Water Act. Noting as of the date of this e-mail much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

Kenny Jaynes
SWG POC

APPROVED JURISDICTIONAL DETERMINATION FORM
U.S. Army Corps of Engineers

This form should be completed by following the instructions provided in Section IV of the JD Form Instructional Guidebook.

SECTION I: BACKGROUND INFORMATION

A. REPORT COMPLETION DATE FOR APPROVED JURISDICTIONAL DETERMINATION (JD): 7 October 2014

B. DISTRICT OFFICE, FILE NAME, AND NUMBER: Galveston District, SWG-2013-00982, Trendmaker Homes, Isolated Wetlands

C. PROJECT LOCATION AND BACKGROUND INFORMATION:

State: Texas County/Parish: Harris City: Houston
Center coordinates of site (lat/long in degree decimal format, NAD-83): Lat. See table° N, Long. see table ° W;
Universal Transverse Mercator: UTM: 15, N., E.,NAD: 83
Name of nearest water body: See Attached Sheet
Name of nearest Traditional Navigable Water (TNW) into which the aquatic resource flows: N/A
Name of watershed or Hydrologic Unit Code (HUC): West Galveston Bay -- 12040204

☒ Check if map/diagram of review area and/or potential jurisdictional areas is/are available upon request.
☐ Check if other sites (e.g., offsite mitigation sites, disposal sites, etc…) are associated with this action and are recorded on a different JD form.

D. REVIEW PERFORMED FOR SITE EVALUATION (CHECK ALL THAT APPLY):

☒ Office (Desk) Determination. Date: 6 October 2014
☒ Field Determination. Date(s): 12 June 2014, 27 August 2014, 11 September 2014, and 30 September 2014

SECTION II: SUMMARY OF FINDINGS

A. RHA SECTION 10 DETERMINATION OF JURISDICTION.

There **Are no** "*navigable waters of the U.S.*" within Rivers and Harbors Act (RHA) jurisdiction (as defined by 33 CFR part 329) in the review area. [***Required***]

☐ Waters subject to the ebb and flow of the tide.
☐ Waters are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. Explain:

B. CWA SECTION 404 DETERMINATION OF JURISDICTION.

There **Are no** "*waters of the U.S.*" within Clean Water Act (CWA) jurisdiction (as defined by 33 CFR part 328) in the review area. [***Required***]

1. **Waters of the U.S.**
   a. **Indicate presence of waters of U.S. in review area (check all that apply):** [1]
      ☐ TNWs, including territorial seas
      ☐ Wetlands adjacent to TNWs
      ☐ Relatively permanent waters[2] (RPWs) that flow directly or indirectly into TNWs
      ☐ Non-RPWs that flow directly or indirectly into TNWs
      ☐ Wetlands directly abutting RPWs that flow directly or indirectly into TNWs
      ☐ Wetlands adjacent to but not directly abutting RPWs that flow directly or indirectly into TNWs
      ☐ Wetlands adjacent to non-RPWs that flow directly or indirectly into TNWs
      ☐ Impoundments of jurisdictional waters
      ☐ Isolated (interstate or intrastate) waters, including isolated wetlands

   b. **Identify (estimate) size of waters of the U.S. in the review area:**
      Non-wetland waters: linear feet: width (ft) and/or acres
      Wetlands: acres

   c. **Limits (boundaries) of jurisdiction** based on: **Pick List**
      Elevation of established OHWM (if known):

2. **Non-regulated waters/wetlands (check if applicable):**[3]
   ☒ Potentially jurisdictional waters and/or wetlands were assessed within the review area and determined to be not jurisdictional. Explain: Please see the attached list for specific wetland identifications and locations. The wetlands within the project boundary listed on the attached sheet are isolated, and do not posses a nexus to commerce. Therefore, it is SWG draft determination that these are not waters of the United States subject to Section 404 of the Clean Water Act. Waters of the United States are defined in 33 CFR 328.3(a).

[1] Boxes checked below shall be supported by completing the appropriate sections in Section III below.
[2] For purposes of this form, an RPW is defined as a tributary that is not a TNW and that typically flows year-round or has continuous flow at least "seasonally" (e.g., typically 3 months).
[3] Supporting documentation is presented in Section III.F.

The vast majority of the subject wetlands have been landcleared, some were excavated, and detention basin(s) were created. The wetlands were identified using the Atlantic Gulf Coast Region Supplement to the 1987 Corps of Engineers Wetland Delineation Manual.

*NOTE: The Corps and the EPA (Mr. Jim Herrington) visited a portion of the site on 4 December 2013 to investigate a purported unauthorized discharge of fill into wetlands associated with a utility right-of-way. Based on the results of our investigation, no wetlands were filled, and the case was closed accordingly.

Because most of the area has been impacted and the subject wetlands are isolated, the exact boudaries (as standard with isolated wetlands) were not verified. Site visits were conducted by the Corps on 12 June 2014, 27 August 2014, 11 September 2014, and 30 September 2014. The majority of the subject wetlands were examined to ensure that they are enclosed wetlands surrounded by uplands. These subject wetlands are seasonal, depressional wetlands, and precipitation is the source of hydrology. The subject wetlands were/are located in mix of tallow forest and prairie ecosystems. A combination of off-site information, in conjunction with on-site data, were used to determine the extent of the wetlands and locations (including LIDAR). All of the wetlands, as identifed per the manual, are surrounded by upland (non-aquatic features).

The attached table provides the nomenclature of the wetland polygon, size, center location of each wetland, distance to the nearest water of the United States, and the distance to the nearest TNW. All center locations and distances are approximate.

To address the possibility of these wetlands being waters of the United States subject to Section 404 of the Clean Water Act, each purpose, as identified in federal regulation 33 CFR 328(a) and the 2 December 2008 Rapanos guidance, will be addressed.

33 CFR 328(a):
(1) These wetlands are not affected by any tidal waters, nor are they currently used, used in the past, or susceptible for use in interstate or foreign commerce.
(2) The subject wetlands are not interstate wetlands and do not cross interstate or tribal boundaries.
(3) The destruction of these isolated, intrastate wetlands would not affect interstate or foreign travelers for recreational or other purposes; would not affect fish or shellfish that could be taken and sold in interstate or foreign commerce; and would not affect the current use, or potential use, for industrial purposes by industries in interstate commerce. 33 CFR 330.2(e) defines "isolated" as those non-tidal waters of the United States that are not part of a surface tributary system of interstate or navigable waters of the United States, and are not adjacent to such tributary waterbodies.
(4) The subject wetlands are not impoundments of waters of the United States.
(5) The subject wetlands are not part of any surface tributary system of waters identified in 1-4.
(6) The subject wetlands are not part of the territorial seas.
(7) The subject wetlands are not adjacent to waters (other than waters that are themselves wetlands) identified in 1-6. Adjacent is defined in 33 CFR 328.3(c) as bordering, contiguous, or neighboring. Wetlands separated from other waters of the United States by man-made dikes or barriers, natural river berms, beach dunes and the like are adjacent wetlands.
(8) The subject wetlands are not prior converted croplands.

To address potential adjacency, both geomorphically and ecologically, SWG has verified that these wetlands are not seperated from waters of the United States by river berms, dunes, man-made dikes and the like, nor are they any of the following:
BORDERING: The subject wetlands, under normal conditions in the hydrologic cycle, are not located along the margin or edge of a water of the United States. These special aquatic sites do not share at least one boundary with a water of the United States (i.e. the high tide line or the ordinary high water mark).
CONTIGUOUS: The subject wetlands, under normal conditions in the hydrologic cycle, do not touch or directly connect to another water of the United States.
NEIGHBORING: The subject wetlands, under normal conditions in the hydrologic cycle, are not located within reasonable close proximity to another water of the United States, either on the horizon or vertical geometric plane. They are not located in either a contiguous or bordering landscape position. They do not have a shared surface hydrologic connection with any water of the United States during expected high flow. These wetlands are physically separated from any water of the United States by more than one hydrology barrier (e.g. man-made dikes, beach dunes, natural river berms, and/or similar obstruction). These wetlands would not allow the exchange of waters via a surface hydrology connection with any water of the United States during expected high flows.

2 December 2008 Rapanos Guidance:
Federal regulation and the Rapanos guidance have the same definition of adjacent. However, the Rapanos guidance provides some clarification and stated that if any one of the following three criteria is present, an adjacent determination could be made.

1) Unbroken Surface or Shallow Sub-Surface Connection: Based on off-site information and site visits, the Corps could not find any unbroken surface or shallow sub-surface connections between the subject wetlands and any jurisdictional waters. Based on the geomorphology, soils, and location of the subject wetlands, the only way that any potential shared hydrology between any of the subject wetlands and the nearest water of the United States would be during a brief and extreme (above normal) storm event. That connection would be at best speculative.

2) Physical Separation: The subject wetlands are not physically separated by man-made dikes or barrier, natural river berms, beach dunes and the like. They are located well inland from the nearest water of the United States.
3) Reasonably Close Proximity: The subject wetlands are not located in a reasonably close proximity that based upon supporting science, one could infer an ecological connection with any jurisdictional waters. This conclusion is based upon the refinement in the Rapanos guidance, which defines the "reasonably close" concept as a wetland that is located reasonably close to a jurisdictional water, in which an aquatic species (e.g. amphibians, or anadramous and catadramous fishes) requires both the jurisdictional water (excluding other wetlands) and the subject wetland for spawning and/or to fulfill their life cycles requirements. Each wetland was evaluated individually and was not evaluated with other wetlands in the area.

In conclusion, the subject wetlands, as determined by SWG, are not located adjacent (bordering, neighboring, or contigious) to any waters of the United States, as defined in 33 CFR 328.3(c). The subject wetlands are isolated, as defined in 33 CFR 330.2(e). The subject wetlands are located above the anticipated high flow of the closest water of the United States (above the100-year floodplain of any water of the United States). They do not have any confined hydrological surface connection, nor any know shallow subsurface connections to any water of the United States. They have also been determined not to be ecologically adjacent, as defined in the Rapanos guidance as being reasonably close such that an ecologic inteconnectivity is beyond speculation or insubstantial. There are not any known species in this georegion that require both the subject wetland and the nearest waterbody (a water of the United States other than an adjacent wetland) to fullfill spawning and/or life cycle requirements. Therefore, it is SWG draft determination that the subject wetlands are isolated, with no known nexus to interstate commerce. As such, they are not subject to federal jurisdiction under Section 404 of the Clean Water Act.

SECTION III: CWA ANALYSIS

A. TNWs AND WETLANDS ADJACENT TO TNWs

The agencies will assert jurisdiction over TNWs and wetlands adjacent to TNWs. If the aquatic resource is a TNW, complete Section III.A.1 and Section III.D.1. only; if the aquatic resource is a wetland adjacent to a TNW, complete Sections III.A.1 and 2 and Section III.D.1.; otherwise, see Section III.B below.

1. **TNW**
Identify TNW:

Summarize rationale supporting determination:

2. **Wetland adjacent to TNW**
Summarize rationale supporting conclusion that wetland is "adjacent":

B. CHARACTERISTICS OF TRIBUTARY (THAT IS NOT A TNW) AND ITS ADJACENT WETLANDS (IF ANY):

This section summarizes information regarding characteristics of the tributary and its adjacent wetlands, if any, and it helps determine whether or not the standards for jurisdiction established under *Rapanos* have been met.

The agencies will assert jurisdiction over non-navigable tributaries of TNWs where the tributaries are "relatively permanent waters" (RPWs), i.e. tributaries that typically flow year-round or have continuous flow at least seasonally (e.g., typically 3 months). A wetland that directly abuts an RPW is also jurisdictional. If the aquatic resource is not a TNW, but has year-round (perennial) flow, skip to Section III.D.2. If the aquatic resource is a wetland directly abutting a tributary with perennial flow, fill out Section III.D.2 and Section III.D.4.

A wetland that is adjacent to but that does not directly abut an RPW requires a significant nexus evaluation. Corps districts and EPA regions will include in the record any available information that documents the existence of a significant nexus between a relatively permanent tributary that is not perennial (and its adjacent wetlands if any) and a traditional navigable water, even though a significant nexus finding is not required as a matter of law.

If the water body[4] is not an RPW, or a wetland directly abutting an RPW, a JD will require additional data to determine if the water body has a significant nexus with a TNW. If the tributary has adjacent wetlands, the significant nexus evaluation must consider the tributary in combination with all of its adjacent wetlands. This significant nexus evaluation that combines, for analytical purposes, the tributary and all of its adjacent wetlands is used whether the review area identified in the JD request is the tributary, or its adjacent wetlands, or both. If the JD covers a tributary with adjacent wetlands, complete Section III.B.1 for the tributary, Section III.B.2 for any onsite wetlands, and Section III.B.3 for all wetlands adjacent to that tributary, both onsite and offsite. The determination whether a significant nexus exists is determined in Section III.C below.

1. **Characteristics of non-TNWs that flow directly or indirectly into TNW**

(i) General Area Conditions:
Watershed size: **Pick List**
Drainage area: **Pick List**
Average annual rainfall: inches
Average annual snowfall: inches

(ii) Physical Characteristics:
(a) Relationship with TNW:
☐ Tributary flows directly into TNW.
☐ Tributary flows through **Pick List** tributaries before entering TNW.

Project waters are **Pick List** river miles from TNW.
Project waters are **Pick List** river miles from RPW.
Project waters are **Pick List** aerial (straight) miles from TNW.
Project waters are **Pick List** aerial (straight) miles from RPW.
Project waters cross or serve as state boundaries. Explain:

Identify flow route to TNW[5]:
Tributary stream order, if known:

[4] Note that the Instructional Guidebook contains additional information regarding swales, ditches, washes, and erosional features generally and in the arid West.
[5] Flow route can be described by identifying, e.g., tributary a, which flows through the review area, to flow into tributary b, which then flows into TNW.

(b) General Tributary Characteristics (check all that apply):

Tributary is: ☐ Natural
☐ Artificial (man-made). Explain:
☐ Manipulated (man-altered). Explain:

Tributary properties with respect to top of bank (estimate):
Average width: feet
Average depth: feet
Average side slopes: **Pick List**

Primary tributary substrate composition (check all that apply):
☐ Silts ☐ Sands ☐ Concrete
☐ Cobbles ☐ Gravel ☐ Muck
☐ Bedrock ☐ Vegetation. Type/% cover:
☐ Other. Explain:

Tributary condition/stability [e.g., highly eroding, sloughing banks]. Explain:
Presence of run/riffle/pool complexes. Explain:
Tributary geometry: **Pick List**
Tributary gradient (approximate average slope): %

(c) Flow:
Tributary provides for: **Pick List**
Estimate average number of flow events in review area/year: **Pick List**
Describe flow regime:
Other information on duration and volume:
Surface flow is: **Pick List.** Characteristics:
Subsurface flow: **Pick List**. Explain findings:
☐ Dye (or other) test performed:

Tributary has (check all that apply):
☐ Bed and banks
☐ OHWM[6] (check all indicators that apply):
☐ clear, natural line impressed on the bank ☐ the presence of litter and debris
☐ changes in the character of soil ☐ destruction of terrestrial vegetation
☐ shelving ☐ the presence of wrack line
☐ vegetation matted down, bent, or absent ☐ sediment sorting
☐ leaf litter disturbed or washed away ☐ scour
☐ sediment deposition ☐ multiple observed or predicted flow events
☐ water staining ☐ abrupt change in plant community
☐ other (list):
☐ Discontinuous OHWM.[7] Explain:

If factors other than the OHWM were used to determine lateral extent of CWA jurisdiction (check all that apply):
☐ High Tide Line indicated by: ☐ Mean High Water Mark indicated by:
☐ oil or scum line along shore objects ☐ survey to available datum;
☐ fine shell or debris deposits (foreshore) ☐ physical markings;
☐ physical markings/characteristics ☐ vegetation lines/changes in vegetation types.
☐ tidal gauges
☐ other (list):

(iii) Chemical Characteristics:
Characterize tributary (e.g., water color is clear, discolored, oily film; water quality; general watershed characteristics, etc.).
Explain:
Identify specific pollutants, if known:

[6]A natural or man-made discontinuity in the OHWM does not necessarily sever jurisdiction (e.g., where the stream temporarily flows underground, or where the OHWM has been removed by development or agricultural practices). Where there is a break in the OHWM that is unrelated to the water body's flow regime (e.g., flow over a rock outcrop or through a culvert), the agencies will look for indicators of flow above and below the break.
[7]Ibid.

(iv) Biological Characteristics. Channel supports (check all that apply):

- ☐ Riparian corridor. Characteristics (type, average width):
- ☐ Wetland fringe. Characteristics:
- ☐ Habitat for:
  - ☐ Federally Listed species. Explain findings:
  - ☐ Fish/spawn areas. Explain findings:
  - ☐ Other environmentally-sensitive species. Explain findings:
  - ☐ Aquatic/wildlife diversity. Explain findings:

2. Characteristics of wetlands adjacent to non-TNW that flow directly or indirectly into TNW

(i) Physical Characteristics:

(a) General Wetland Characteristics:

Properties:

Wetland size: acres

Wetland type. Explain:

Wetland quality. Explain:

Project wetlands cross or serve as state boundaries. Explain:

(b) General Flow Relationship with Non-TNW:

Flow is: **Pick List**. Explain:

Surface flow is**: Pick List**

Characteristics:

Subsurface flow: **Pick List**. Explain findings:

- ☐ Dye (or other) test performed:

(c) Wetland Adjacency Determination with Non-TNW:

- ☐ Directly abutting
- ☐ Not directly abutting
  - ☐ Discrete wetland hydrologic connection. Explain:
  - ☐ Ecological connection. Explain:
  - ☐ Separated by berm/barrier. Explain:

(d) Proximity (Relationship) to TNW

Project wetlands are **Pick List** river miles from TNW.

Project waters are **Pick List** aerial (straight) miles from TNW.

Flow is from: **Pick List.**

Estimate approximate location of wetland as within the **Pick List** floodplain.

(ii) Chemical Characteristics:

Characterize wetland system (e.g., water color is clear, brown, oil film on surface; water quality; general watershed characteristics; etc.). Explain:

Identify specific pollutants, if known:

(iii) Biological Characteristics. Wetland supports (check all that apply):

- ☐ Riparian buffer. Characteristics (type, average width):
- ☐ Vegetation type/percent cover. Explain:
- ☐ Habitat for:
  - ☐ Federally Listed species. Explain findings:
  - ☐ Fish/spawn areas. Explain findings:
  - ☐ Other environmentally-sensitive species. Explain findings:
  - ☐ Aquatic/wildlife diversity. Explain findings:

3. Characteristics of all wetlands adjacent to the tributary (if any)

All wetland(s) being considered in the cumulative analysis: **Pick List**

Approximately ( ) acres in total are being considered in the cumulative analysis.

For each wetland, specify the following:

Directly abuts? (Y/N)	Size (in acres)	Directly abuts? (Y/N)	Size (in acres)

Summarize overall biological, chemical and physical functions being performed:

C. SIGNIFICANT NEXUS DETERMINATION

A significant nexus analysis will assess the flow characteristics and functions of the tributary itself and the functions performed by any wetlands adjacent to the tributary to determine if they significantly affect the chemical, physical, and biological integrity of a TNW. For each of the following situations, a significant nexus exists if the tributary, in combination with all of its adjacent wetlands, has more than a speculative or insubstantial effect on the chemical, physical and/or biological integrity of a TNW. Considerations when evaluating significant nexus include, but are not limited to the volume, duration, and frequency of the flow of water in the tributary and its proximity to a TNW, and the functions performed by the tributary and all its adjacent wetlands. It is not appropriate to determine significant nexus based solely on any specific threshold of distance (e.g. between a tributary and its adjacent wetland or between a tributary and the TNW). Similarly, the fact an adjacent wetland lies within or outside of a floodplain is not solely determinative of significant nexus.

Draw connections between the features documented and the effects on the TNW, as identified in the *Rapanos* Guidance and discussed in the Instructional Guidebook. Factors to consider include, for example:

- Does the tributary, in combination with its adjacent wetlands (if any), have the capacity to carry pollutants or flood waters to TNWs, or to reduce the amount of pollutants or flood waters reaching a TNW?
- Does the tributary, in combination with its adjacent wetlands (if any), provide habitat and lifecycle support functions for fish and other species, such as feeding, nesting, spawning, or rearing young for species that are present in the TNW?
- Does the tributary, in combination with its adjacent wetlands (if any), have the capacity to transfer nutrients and organic carbon that support downstream foodwebs?
- Does the tributary, in combination with its adjacent wetlands (if any), have other relationships to the physical, chemical, or biological integrity of the TNW?

Note: the above list of considerations is not inclusive and other functions observed or known to occur should be documented below:

1. **Significant nexus findings for non-RPW that has no adjacent wetlands and flows directly or indirectly into TNWs.** Explain findings of presence or absence of significant nexus below, based on the tributary itself, then go to Section III.D:

2. **Significant nexus findings for non-RPW and its adjacent wetlands, where the non-RPW flows directly or indirectly into TNWs.** Explain findings of presence or absence of significant nexus below, based on the tributary in combination with all of its adjacent wetlands, then go to Section III.D:

3. **Significant nexus findings for wetlands adjacent to an RPW but that do not directly abut the RPW.** Explain findings of presence or absence of significant nexus below, based on the tributary in combination with all of its adjacent wetlands, then go to Section III.D:

D. DETERMINATIONS OF JURISDICTIONAL FINDINGS. THE SUBJECT WATERS/WETLANDS ARE (CHECK ALL THAT APPLY):

1. **TNWs and Adjacent Wetlands.** Check all that apply and provide size estimates in review area:
   ☐ TNWs: linear feet width (ft), Or, acres.
   ☐ Wetlands adjacent to TNWs: acres.

2. **RPWs that flow directly or indirectly into TNWs.**
   ☐ Tributaries of TNWs where tributaries typically flow year-round are jurisdictional. Provide data and rationale indicating that tributary is perennial:
   ☐ Tributaries of TNW where tributaries have continuous flow “seasonally” (e.g., typically three months each year) are jurisdictional. Data supporting this conclusion is provided at Section III.B. Provide rationale indicating that tributary flows seasonally:

Provide estimates for jurisdictional waters in the review area (check all that apply):

☐ Tributary waters: linear feet width (ft)
☐ Other non-wetland waters: acres
Identify type(s) of waters:

3. Non-RPWs[8] that flow directly or indirectly into TNWs.

☐ Water body that is not a TNW or an RPW, but flows directly or indirectly into a TNW, and it has a significant nexus with a TNW is jurisdictional. Data supporting this conclusion is provided at Section III.C.

Provide estimates for jurisdictional waters within the review area (check all that apply):

☐ Tributary waters: linear feet width (ft).
☐ Other non-wetland waters: acres
Identify type(s) of waters:

4. Wetlands directly abutting an RPW that flow directly or indirectly into TNWs.

☐ Wetlands directly abut RPW and thus are jurisdictional as adjacent wetlands.

☐ Wetlands directly abutting an RPW where tributaries typically flow year-round. Provide data and rationale indicating that tributary is perennial in Section III.D.2, above. Provide rationale indicating that wetland is directly abutting an RPW:

☐ Wetlands directly abutting an RPW where tributaries typically flow "seasonally." Provide data indicating that tributary is seasonal in Section III.B and rationale in Section III.D.2, above. Provide rationale indicating that wetland is directly abutting an RPW:

Provide acreage estimates for jurisdictional wetlands in the review area: acres

5. Wetlands adjacent to but not directly abutting an RPW that flow directly or indirectly into TNWs.

☐ Wetlands that do not directly abut an RPW, but when considered in combination with the tributary to which they are adjacent and with similarly situated adjacent wetlands, have a significant nexus with a TNW are jurisidictional. Data supporting this conclusion is provided at Section III.C.

Provide acreage estimates for jurisdictional wetlands in the review area: acres

6. Wetlands adjacent to non-RPWs that flow directly or indirectly into TNWs.

☐ Wetlands adjacent to such waters, and have when considered in combination with the tributary to which they are adjacent and with similarly situated adjacent wetlands, have a significant nexus with a TNW are jurisdictional. Data supporting this conclusion is provided at Section III.C.

Provide estimates for jurisdictional wetlands in the review area: acres

7. Impoundments of jurisdictional waters.[9]

As a general rule, the impoundment of a jurisdictional tributary remains jurisdictional.

☐ Demonstrate that impoundment was created from "waters of the U.S.," or
☐ Demonstrate that water meets the criteria for one of the categories presented above (1-6), or
☐ Demonstrate that water is isolated with a nexus to commerce (see E below).

E. ISOLATED [INTERSTATE OR INTRA-STATE] WATERS, INCLUDING ISOLATED WETLANDS, THE USE, DEGRADATION OR DESTRUCTION OF WHICH COULD AFFECT INTERSTATE COMMERCE, INCLUDING ANY SUCH WATERS (CHECK ALL THAT APPLY):[10]

☐ which are or could be used by interstate or foreign travelers for recreational or other purposes.
☐ from which fish or shellfish are or could be taken and sold in interstate or foreign commerce.
☐ which are or could be used for industrial purposes by industries in interstate commerce.
☐ Interstate isolated waters. Explain:
☐ Other factors. Explain:

Identify water body and summarize rationale supporting determination:

[8] See Footnote # 3.
[9] To complete the analysis refer to the key in Section III.D.6 of the Instructional Guidebook.
[10] **Prior to asserting or declining CWA jurisdiction based solely on this category, Corps Districts will elevate the action to Corps and EPA HQ for review consistent with the process described in the Corps/EPA *Memorandum Regarding CWA Act Jurisdiction Following Rapanos.***

Provide estimates for jurisdictional waters in the review area (check all that apply):

☐ Tributary waters: linear feet width (ft)

☐ Other non-wetland waters: acres

Identify type(s) of waters:

☐ Wetlands: acres

F. NON-JURISDICTIONAL WATERS, INCLUDING WETLANDS (CHECK ALL THAT APPLY):

☐ If potential wetlands were assessed within the review area, these areas did not meet the criteria in the 1987 Corps of Engineers Wetland Delineation Manual and/or appropriate Regional Supplements.

☒ Review area included isolated waters with no substantial nexus to interstate (or foreign) commerce.

☒ Prior to the Jan 2001 Supreme Court decision in "*SWANCC*," the review area would have been regulated based solely on the "Migratory Bird Rule" (MBR).

☐ Waters do not meet the "Significant Nexus" standard, where such a finding is required for jurisdiction. Explain:

☐ Other: (explain, if not covered above):

Provide acreage estimates for non-jurisdictional waters in the review area, where the sole potential basis of jurisdiction is the MBR factors (i.e., presence of migratory birds, presence of endangered species, use of water for irrigated agriculture), using best professional judgment (check all that apply):

☐ Non-wetland waters (i.e., rivers, streams): linear feet width (ft).

☐ Lakes/ponds: acres.

☐ Other non-wetland waters: acres. List type of aquatic resource:

☒ Wetlands: **See attached list** acres.

Provide acreage estimates for non-jurisdictional waters in the review area that do not meet the "Significant Nexus" standard, where such a finding is required for jurisdiction (check all that apply):

☐ Non-wetland waters (i.e., rivers, streams): linear feet, width (ft).

☐ Lakes/ponds: acres.

☐ Other non-wetland waters: acres. List type of aquatic resource:

☐ Wetlands: acres.

SECTION IV: DATA SOURCES.

A. SUPPORTING DATA. Data reviewed for JD (check all that apply - checked items shall be included in case file and, where checked and requested, appropriately reference sources below):

☒ Maps, plans, plots or plat submitted by or on behalf of the applicant/consultant:

☒ Data sheets prepared/submitted by or on behalf of the applicant/consultant.

☐ Office concurs with data sheets/delineation report.

☐ Office does not concur with data sheets/delineation report

☐ Data sheets prepared by the Corps:

☐ Corps navigable waters' study:

☒ U.S. Geological Survey Hydrologic Atlas: **West Galveston Bay -- 12040204**

☐ USGS NHD data

☒ USGS 8 and 12 digit HUC maps

☐ Galveston District's Approved List of Navigable Waters

☒ U.S. Geological Survey map(s). Cite scale & quad name: **1:24,000 Friendswood and League City, Texas quadrangle**

☒ USDA Natural Resources Conservation Service Soil Survey. Citation: **Web Soil Survey, accessed 5 December 2013**

☒ National wetlands inventory map(s). Cite name: **USFWS NWI, accessed 3 December 2013**

☐ State/Local wetland inventory map(s):

☒ FEMA/FIRM maps: **48201C1060L and 48201C1080L**

☐ 100-year Floodplain Elevation is: (National Geodectic Vertical Datum of 1929)

☒ Photographs: ☒ Aerial (Name & Date): **1995, 2009 Infrared; Google Earth aerials dated 1943-2014**

or ☒ Other (Name & Date): **Site Visit Photographs, dated 12 June 2014, 27 August 2014, 11 September 2014, and 30 September 2014**

☐ Previous determination(s). File no. and date of response letter:

☐ Applicable/supporting case law:

☐ Applicable/supporting scientific literature:

☐ Other information (please specify):

B. ADDITIONAL COMMENTS TO SUPPORT JD: Please see the attached list for specific wetland identifications and locations. The wetlands within the project boundary listed on the attached sheet are isolated, and do not posses a nexus to commerce. Therefore, it is SWG draft determination that these are not waters of the United States subject to Section 404 of the Clean Water Act. Waters of the United States are defined in 33 CFR 328.3(a).

The vast majority of the subject wetlands have been landcleared, some were excavated, and detention basin(s) were created. The wetlands were identified using the Atlantic Gulf Coast Region Supplement to the 1987 Corps of Engineers Wetland Delineation Manual.

*NOTE: The Corps and the EPA (Mr. Jim Herrington) visited a portion of the site on 4 December 2013 to investigate a purported unauthorized discharge of fill into wetlands associated with a utility right-of-way. Based on the results of our investigation, no wetlands were filled, and the case was closed accordingly.

Because most of the area has been impacted and the subject wetlands are isolated, the exact boudaries (as standard with isolated wetlands) were not verified. Site visits were conducted by the Corps on 12 June 2014, 27 August 2014, 11 September 2014, and 30 September 2014. The majority of the subject wetlands were examined to ensure that they are enclosed wetlands surrounded by uplands. These subject wetlands are seasonal, depressional wetlands, and precipitation is the source of hydrology. The subject wetlands were/are located in mix of tallow forest and prairie ecosystems. A combination of off-site information, in conjunction with on-site data, were used to determine the extent of the wetlands and locations (including LIDAR). All of the wetlands, as identifed per the manual, are surrounded by upland (non-aquatic features).

The attached table provides the nomenclature of the wetland polygon, size, center location of each wetland, distance to the nearest water of the United States, and the distance to the nearest TNW. All center locations and distances are approximate.

To address the possibility of these wetlands being waters of the United States subject to Section 404 of the Clean Water Act, each purpose, as identified in federal regulation 33 CFR 328(a) and the 2 December 2008 Rapanos guidance, will be addressed.

33 CFR 328(a):
(1) These wetlands are not affected by any tidal waters, nor are they currently used, used in the past, or susceptible for use in interstate or foreign commerce.
(2) The subject wetlands are not interstate wetlands and do not cross interstate or tribal boundaries.
(3) The destruction of these isolated, intrastate wetlands would not affect interstate or foreign travelers for recreational or other purposes; would not affect fish or shellfish that could be taken and sold in interstate or foreign commerce; and would not affect the current use, or potential use, for industrial purposes by industries in interstate commerce. 33 CFR 330.2(e) defines "isolated" as those non-tidal waters of the United States that are not part of a surface tributary system of interstate or navigable waters of the United States, and are not adjacent to such tributary waterbodies.
(4) The subject wetlands are not impoundments of waters of the United States.
(5) The subject wetlands are not part of any surface tributary system of waters identified in 1-4.
(6) The subject wetlands are not part of the territorial seas.
(7) The subject wetlands are not adjacent to waters (other than waters that are themselves wetlands) identified in 1-6. Adjacent is defined in 33 CFR 328.3(c) as bordering, contiguous, or neighboring. Wetlands separated from other waters of the United States by man-made dikes or barriers, natural river berms, beach dunes and the like are adjacent wetlands.
(8) The subject wetlands are not prior converted croplands.

To address potential adjacency, both geomorphically and ecologically, SWG has verified that these wetlands are not seperated from waters of the United States by river berms, dunes, man-made dikes and the like, nor are they any of the following:
BORDERING: The subject wetlands, under normal conditions in the hydrologic cycle, are not located along the margin or edge of a water of the United States. These special aquatic sites do not share at least one boundary with a water of the United States (i.e. the high tide line or the ordinary high water mark).
CONTIGUOUS: The subject wetlands, under normal conditions in the hydrologic cycle, do not touch or directly connect to another water of the United States.
NEIGHBORING: The subject wetlands, under normal conditions in the hydrologic cycle, are not located within reasonable close proximity to another water of the United States, either on the horizon or vertical geometric plane. They are not located in either a contiguous or bordering landscape position. They do not have a shared surface hydrologic connection with any water of the United States during expected high flow. These wetlands are physically separated from any water of the United States by more than one hydrology barrier (e.g. man-made dikes, beach dunes, natural river berms, and/or similar obstruction). These wetlands would not allow the exchange of waters via a surface hydrology connection with any water of the United States during expected high flows.

2 December 2008 Rapanos Guidance:
Federal regulation and the Rapanos guidance have the same definition of adjacent. However, the Rapanos guidance provides some clarification and stated that if any one of the following three criteria is present, an adjacent determination could be made.

1) Unbroken Surface or Shallow Sub-Surface Connection: Based on off-site information and site visits, the Corps could not find any unbroken surface or shallow sub-surface connections between the subject wetlands and any jurisdictional waters. Based on the geomorphology, soils, and location of the subject wetlands, the only way that any potential shared hydrology between any of the subject wetlands and the nearest water of the United States would be during a brief and extreme (above normal) storm event. That connection would be at best speculative.
2) Physical Separation: The subject wetlands are not physically separated by man-made dikes or barrier, natural river berms, beach dunes and the like. They are located well inland from the nearest water of the United States.

3) Reasonably Close Proximity: The subject wetlands are not located in a reasonably close proximity that based upon supporting science, one could infer an ecological connection with any jurisdictional waters. This conclusion is based upon the refinement in the Rapanos guidance, which defines the “reasonably close” concept as a wetland that is located reasonably close to a jurisdictional water, in which an aquatic species (e.g. amphibians, or anadramous and catadramous fishes) requires both the jurisdictional water (excluding other wetlands) and the subject wetland for spawning and/or to fulfill their life cycles requirements. Each wetland was evaluated individually and was not evaluated with other wetlands in the area.

In conclusion, the subject wetlands, as determined by SWG, are not located adjacent (bordering, neighboring, or contigious) to any waters of the United States, as defined in 33 CFR 328.3(c). The subject wetlands are isolated, as defined in 33 CFR 330.2(e). The subject wetlands are located above the anticipated high flow of the closest water of the United States (above the100-year floodplain of any water of the United States). They do not have any confined hydrological surface connection, nor any know shallow subsurface connections to any water of the United States. They have also been determined not to be ecologically adjacent, as defined in the Rapanos guidance as being reasonably close such that an ecologic inteconnectivity is beyond speculation or insubstantial. There are not any known species in this georegion that require both the subject wetland and the nearest waterbody (a water of the United States other than an adjacent wetland) to fullfill spawning and/or life cycle requirements. Therefore, it is SWG draft determination that the subject wetlands are isolated, with no known nexus to interstate commerce. As such, they are not subject to federal jurisdiction under Section 404 of the Clean Water Act.

SWG-2013-00982 ISOLATED AQUATIC RESOURCE LIST

NAME	Appx SIZE (acres)	LAT	LON	APPX DISTANCE TO NEAREST WATERWAY	WATERWAY	APPX AERIAL DISTANCE TO TNW (Armand Bayou)
W1	0.3	29.611708	-95.134699	0.4 mile	Unnamed Tributary of Horsepen Bayou	2.2 miles
W2	0.8	29.610331	-95.133726	0.4 mile	Unnamed Tributary of Horsepen Bayou	2.2 miles
W3	0.8	29.609107	-95.132673	0.5 mile	Unnamed Tributary of Horsepen Bayou	2.1 miles
W4	2.8	29.607994	-95.131841	0.5 mile	Unnamed Tributary of Horsepen Bayou	2 miles
W5	0.3	29.606954	-95.132387	0.4 mile	Unnamed Tributary of Horsepen Bayou	2.1 miles
W6	0.5	29.606667	-95.131201	0.4 mile	Unnamed Tributary of Horsepen Bayou	2 miles
W7	0.7	29.605901	-95.130179	0.5 mile	Unnamed Tributary of Horsepen Bayou	2 miles
W8	0.5	29.614007	-95.132907	0.6 mile	Unnamed Tributary of Horsepen Bayou	2.1 miles
W9	0.4	29.612304	-95.133155	0.5 mile	Unnamed Tributary of Horsepen Bayou	2.1 miles
W10	0.2	29.611412	-95.131607	0.6 mile	Unnamed Tributary of Horsepen Bayou	2 miles
W11	0.2	29.61191	-95.130328	0.6 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W12	0.4	29.610789	-95.131135	0.6 mile	Unnamed Tributary of Horsepen Bayou	2 miles
W13	0.3	29.610094	-95.131644	0.6 mile	Unnamed Tributary of Horsepen Bayou	2 miles
W14	0.2	29.609326	-95.129487	0.6 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W15	0.3	29.607943	-95.128802	0.6 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W16	0.9	29.607661	-95.127332	0.7 mile	Unnamed Tributary of Horsepen Bayou	1.8 miles
W17	0.2	29.616419	-95.129723	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W18	7.7	29.615485	-95.130939	0.8 mile	Unnamed Tributary of Horsepen Bayou	2 miles
W19	1.2	29.615581	-95.129717	0.8 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W20	0.2	29.61432	-95.129734	0.8 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W21	1.4	29.614759	-95.128585	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.8 miles
W22	0.1	29.614174	-95.129316	0.8 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles

SWG-2013-00982 ISOLATED AQUATIC RESOURCE LIST

NAME	Appx SIZE (acres)	LAT	LON	APPX DISTANCE TO NEAREST WATERWAY	WATERWAY	APPX AERIAL DISTANCE TO TNW (Armand Bayou)
W23	1.0	29.613463	-95.129563	0.7 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W24	0.2	29.612732	-95.128739	0.8 mile	Unnamed Tributary of Horsepen Bayou	1.9 miles
W25	0.4	29.611502	-95.128058	0.8 mile	Unnamed Tributary of Horsepen Bayou	1.8 miles
W26	0.8	29.608693	-95.12577	0.8 mile	Unnamed Tributary of Horsepen Bayou	1.7 miles
W27	0.1	29.615705	-95.128168	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.8 miles
W28	0.3	29.615689	-95.126747	1 mile	Unnamed Tributary of Horsepen Bayou	1.7 miles
W29	0.5	29.614493	-95.126351	1 mile	Unnamed Tributary of Horsepen Bayou	1.7 miles
W30	4.8	29.613626	-95.125351	1 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles
W31	0.5	29.612676	-95.126533	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.7 miles
W32	0.6	29.61239	-95.124997	1 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles
W33	0.8	29.611278	-95.124373	1 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles
W34	0.5	29.616599	-95.124539	1.1 miles	Unnamed Tributary of Horsepen Bayou	1.6 miles
W35	1.2	29.615778	-95.125068	1.1 miles	Unnamed Tributary of Horsepen Bayou	1.6 miles
W36	0.6	29.615828	-95.123458	1.2 miles	Unnamed Tributary of Horsepen Bayou	1.5 miles
W37	4.4	29.614883	-95.122837	1.2 miles	Unnamed Tributary of Horsepen Bayou	1.5 miles
W38	4.9	29.613848	-95.121914	1.2 miles	Unnamed Tributary of Horsepen Bayou	1.4 miles
W39	1.0	29.61253	-95.122214	1.1 miles	Unnamed Tributary of Horsepen Bayou	1.5 miles
W40	1.2	29.611751	-95.123154	1 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles
W41	0.6	29.611747	-95.121897	1.1 miles	Unnamed Tributary of Horsepen Bayou	1.4 miles
W42	0.6	29.612762	-95.119678	1.3 miles	Armand Bayou	1.3 miles
W43	0.7	29.616465	-95.120958	1.4 miles	Armand Bayou	1.4 miles
W44	0.3	29.616780	-95.119189	1.3 miles	Armand Bayou	1.3 miles

SWG-2013-00982 ISOLATED AQUATIC RESOURCE LIST

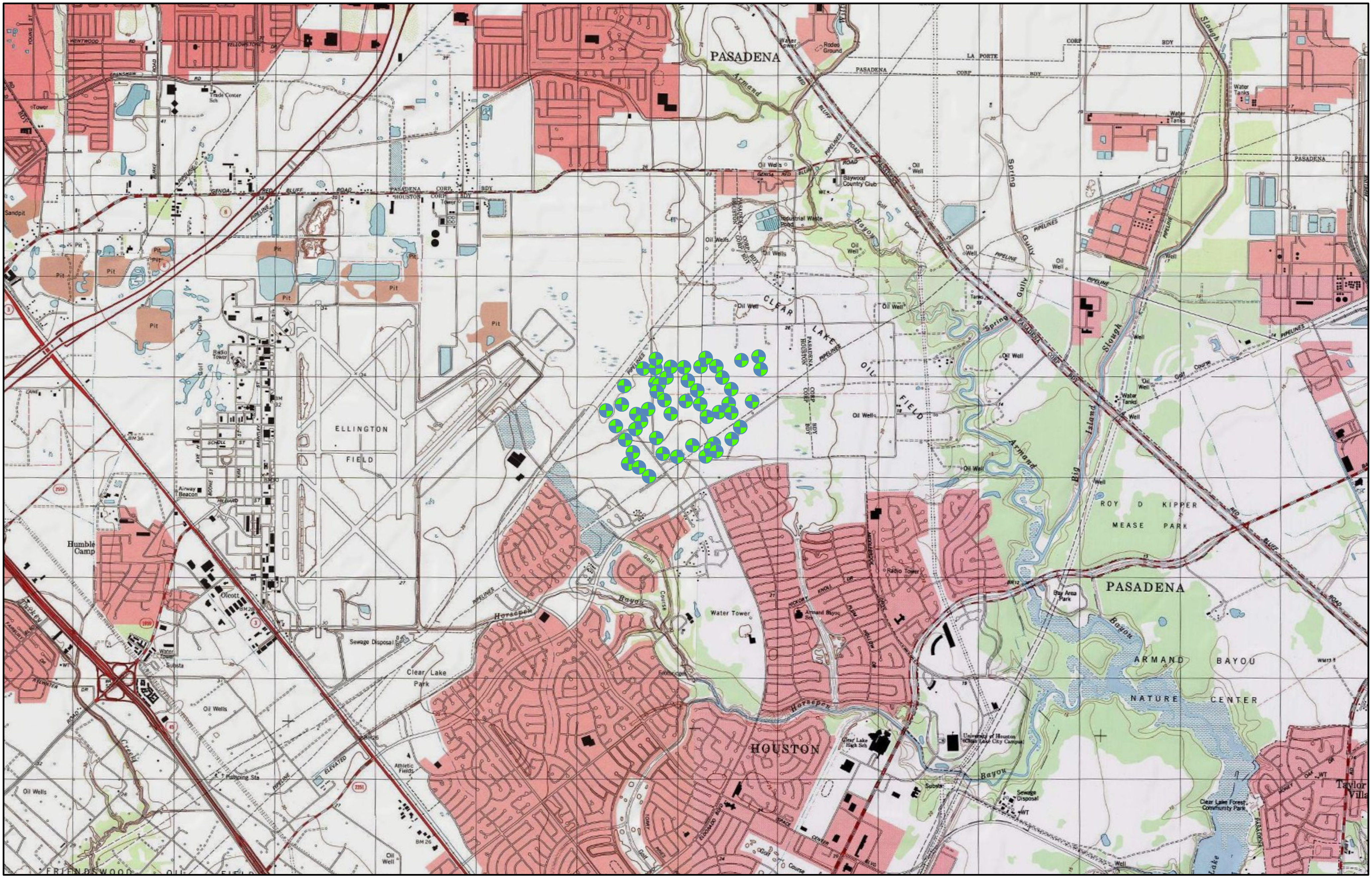
NAME	Appx SIZE (acres)	LAT	LON	APPX DISTANCE TO NEAREST WATERWAY	WATERWAY	APPX AERIAL DISTANCE TO TNW (Armand Bayou)
W45	1.0	29.615638	-95.118919	1.2 miles	Armand Bayou	1.2 miles
W46	0.6	29.610402	-95.12094	1.1 miles	Unnamed Tributary of Horsepen Bayou	1.4 miles
W47	0.1	29.609339	-95.121737	1 mile	Unnamed Tributary of Horsepen Bayou	1.4 miles
W48	0.8	29.608952	-95.123532	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles
W49	0.1	29.608445	-95.123877	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles
W50	0.02	29.608263	-95.123326	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles
W51	0.2	29.607768	-95.124463	0.9 mile	Unnamed Tributary of Horsepen Bayou	1.6 miles

TOTAL: **49.2 acres**

SWG-2013-00982

Trendmaker Homes

USGS Topographic Maps
Pasadena, La Porte, Friendswood, and League City, Texas Quadrangles



N
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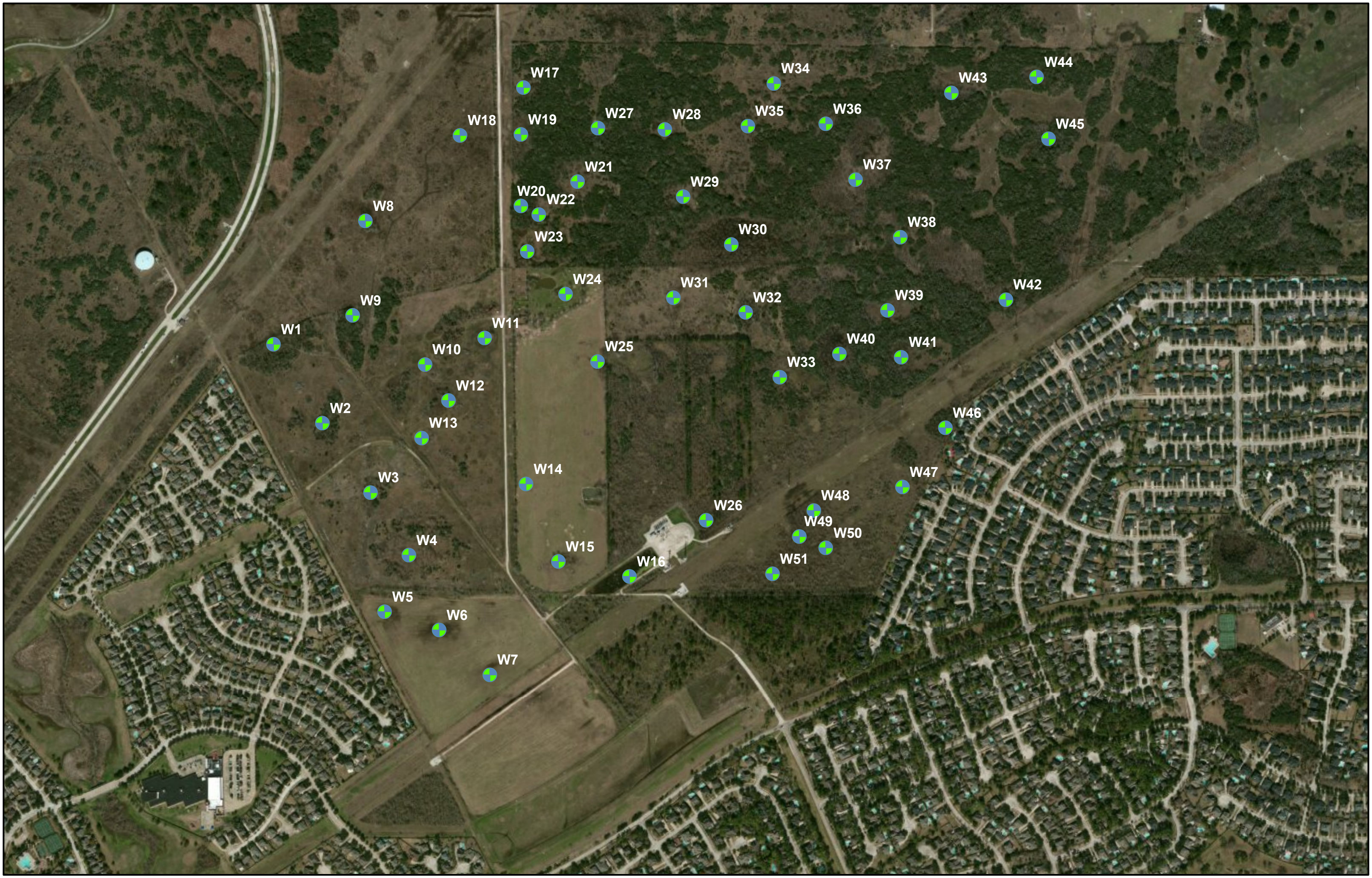
USACE SWG-PE-RC/KS/Created: 7 Octoboer 2014

Legend

Isolated Wetlands

Undated ESRI Image
Friendswood and Leage City, Texas Quadrangles

SWG-2013-00982
Trendmaker Homes



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0 0.125 0.25 0.5 Miles

USACE SWG-PE-RC/KS/Created: 7 Octoboer 2014

Legend

Isolated Wetlands

Teague, Kenneth

From: Parrish, Sharon
Sent: Monday, October 20, 2014 4:08 PM
To: Kenny Jaynes
Cc: Teague, Kenneth
Subject: FW: JD Elevation

Dear Kenny - Thank you for providing your e-mail of October 7, 2014 initiating the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations for “51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)”. We elect to elevate the review to our Regional Administrator (RA) and so are notifying you in writing.

The rationale for EPA’s position on this is based on: 1) We believe that these wetlands are adjacent to a Relatively Permanent Water (RPW); 2) We believe that these wetlands would likely be connected hydrologically to an RPW and TNW during higher rainfall events, via overland flow and flow through swales and/or ditches, and that such events are within the definition of “normal” environmental conditions for this region. 3) While we agree that there are factors other than the water quality functions of wetlands that may play a role in determining whether or not a significant nexus exists between a wetland and an RPW and TNW, water quality alone can constitute such a significant nexus. Finally, we would like to reiterate that there are several high quality peer-reviewed, published studies of very similar coastal Texas depressional wetlands’ hydrology and water quality (Wilcox et al. 2011; Forbes et al. 2012), which document connectivity to downstream waters, as well as a significant nexus between them and downstream waters via their water quality functions. In this particular case, we believe these studies clearly apply, as the sites that were studied are very nearby and are very similar to those you have determined not to be jurisdictional.

All this said, in order to be consistent with recent similar EPA reviews of COE JD’s, we must acknowledge that these reviews include some uncertainty. We have not visited the site and we have limited information to review. If you have any questions, please contact Mr. Kenneth Teague of my staff at (214) 665-6687.

Sincerely,

Sharon Fancy Parrish
Chief
Wetlands Section
EPA Region 6

References

Forbes, M. G., J. Back, and R. D. Doyle. 2012. “Nutrient Transformation and Retention by Coastal Prairie Wetlands, Upper Gulf Coast, Texas.” *Wetlands*, 32(4), 705–715.

Wilcox, B. P., D. D. Dean, J. S. Jacob, and A. Sipocz. 2011. “Evidence of Surface Connectivity for Texas Gulf Coast Depressional Wetlands.” *Wetlands*, 31(3), 451–458.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TEXAS 75202 – 2733

Office of the Regional Administrator

October 29, 2014

MEMORANDUM

SUBJECT: Jurisdictional Determinations

FROM: for Ron Curry
Regional Administrator

TO: John Goodin
Director, Wetlands Division

We are unable to come to an agreement with the Corps of Engineers, Galveston District regarding the jurisdictional status of 51 wetlands in the League City are of Harris County, Texas, under the permit application number SWG-2013-00982. Therefore, we are elevating this jurisdictional determination to the U.S. Environmental Protection Agency Headquarters. Attachments are included providing information to document why we believe the wetland sites should be considered jurisdictional. We will continue to work with Galveston District to gather additional information and will provide it to you as we receive it.

If you have any questions, please contact me at (214) 665-2100, or Mr. Ken Teague, Environmental Scientist, at (214) 665-6687.

Attachments

cc: Colonel Richard P. Pannell
U.S. Army Corps of Engineers, Galveston District

Jurisdictional Determination
SWG-2013-00982

Background on CWA Jurisdiction

The agencies will assert Clean Water Act jurisdiction over wetlands adjacent to traditional navigable waters or non-wetland interstate waters or to another water of the U.S. where such wetlands have a significant nexus with downstream traditional navigable or interstate waters. Adjacent wetlands will be considered to have a significant nexus if they, alone or in combination with similarly situated wetlands, have an effect on the chemical, physical, or biological integrity of traditional navigable waters or interstate waters that is more than "speculative or insubstantial." Wetlands adjacent to traditional navigable waters or non-wetland interstate waters are *per se* jurisdictional and do not require a showing of significant nexus.

An adjacent wetland is jurisdictional where such wetland meets the definition of "adjacent" as that term is defined in the agencies' regulations and is either: (1) Adjacent to a traditional navigable water or non-wetland interstate water; or (2) Adjacent to a tributary, lake, reservoir, or other jurisdictional water (except another wetland) and either alone or in combination with other adjacent wetlands in the watershed has a significant nexus to the nearest downstream traditional navigable or interstate water. The term *adjacent* means bordering, contiguous, or neighboring.

An unbroken surface or shallow sub-surface hydrologic connection to jurisdictional waters may be established by a physical feature or discrete conveyance that supports periodic flow between the wetland and a jurisdictional water. Water does not have to be continuously present in this hydrologic connection and the flow between the wetland and the jurisdictional water may move in either or both directions. The hydrologic connection need not itself be a water of the U.S.

SWG-2013-00982

We consider the subject wetlands to be *adjacent*. We consider the subject wetlands to be *adjacent to either, or possibly both, a traditional navigable water* (Armand Bayou), and/or a *tributary* (Horsepen Bayou, a RPW). In the case of the latter, we consider the subject wetlands, *in combination with other adjacent wetlands in the watershed, to have a significant nexus to the nearest downstream traditional navigable water* (Armand Bayou). To the extent the subject wetlands are adjacent to a TNW (Armand Bayou), demonstration of a significant nexus is not needed. On the other hand, to the extent the subject wetlands are adjacent to an RPW (Horesepen Bayou), it is necessary to demonstrate a significant nexus.

We consider the subject wetlands to have *an unbroken surface hydrologic connection to jurisdictional waters via physical features* (swales) and *discrete conveyances* (drainage ditches). Water is not continuously present in the hydrologic connection. Flow between the subject wetlands and the jurisdictional waters (Armand Bayou, Horsepen Bayou) moves only in one direction- from the wetlands to the jurisdictional waters. While in some cases the hydrologic connections may be waters of the U.S. (e.g. some swales), most probably are not (e.g. ditches, some swales).

Our argument for *an unbroken surface hydrologic connection to jurisdictional waters via physical features* (swales) and *discrete conveyances* (drainage ditches), is supported by:

- The existence of swales in the landscape between depressional wetlands, and between these wetlands and jurisdictional waters (RPW, TNW; Wilcox et al. 2011; Fig. 1).
- The existence of several drainage ditches connecting the landscape in the vicinity of the subject wetlands, and Armand Bayou and Horsepen Bayou (Figs. 2-3).
- Measurements of water flow from very similar depressional wetlands nearby, to jurisdictional waters, under specific precipitation regimes (Wilcox et al. 2011).

Figure 1. Headwater wetland swales. From the TAMU study site at ABNC. Note the shallow swales. These convey water across the landscape, largely wetlands themselves.

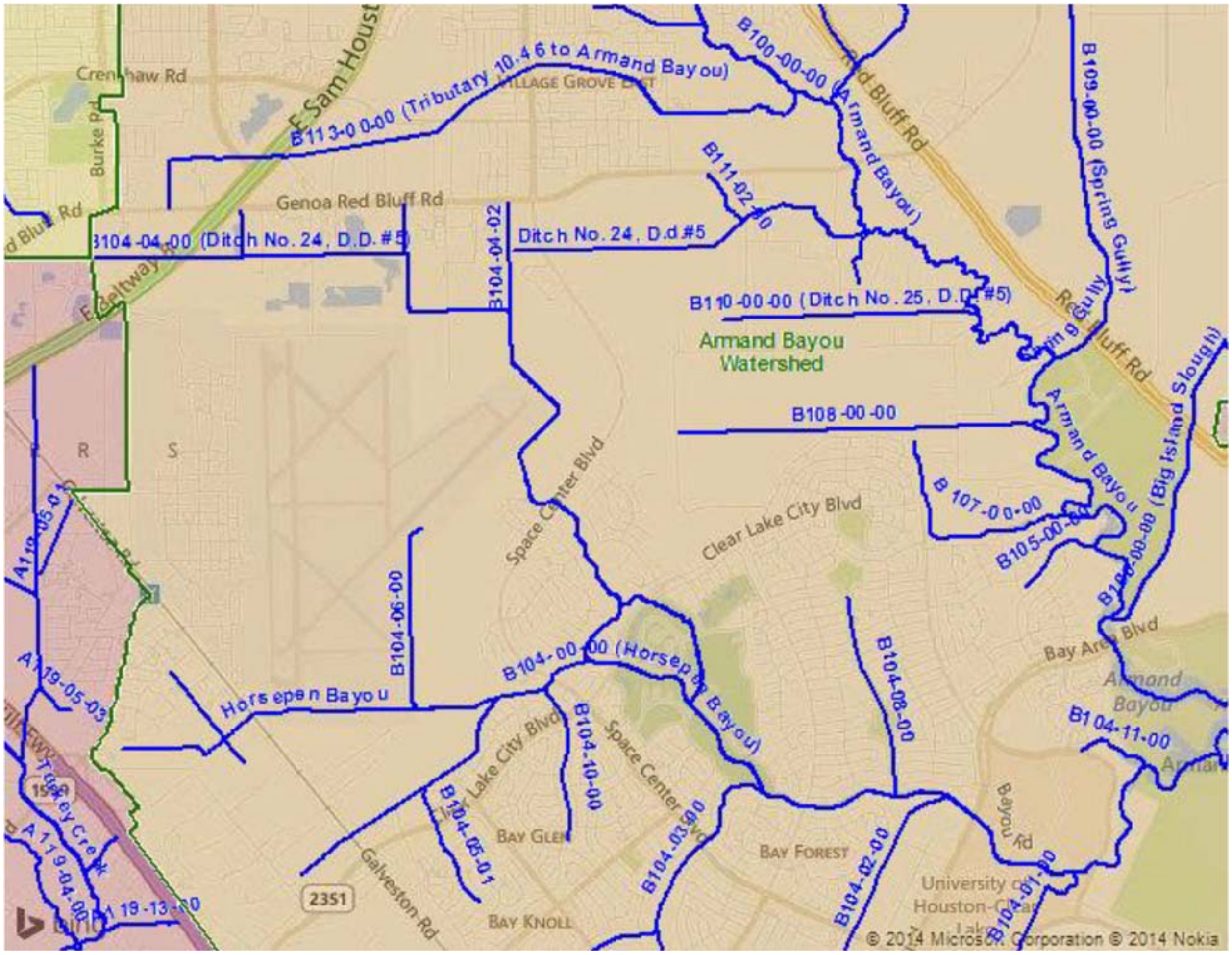

Figure 2. Drainage system map of the vicinity of the subject wetlands. Ditch B1080-00-00 appears to drain much of the subject area to Armand Bayou, a TNW. It is also possible that some of the subject wetlands may drain into Ditch B104-04-02, thence into Horsepen Bayou (an RPW) just north of Clear Lake City Blvd.

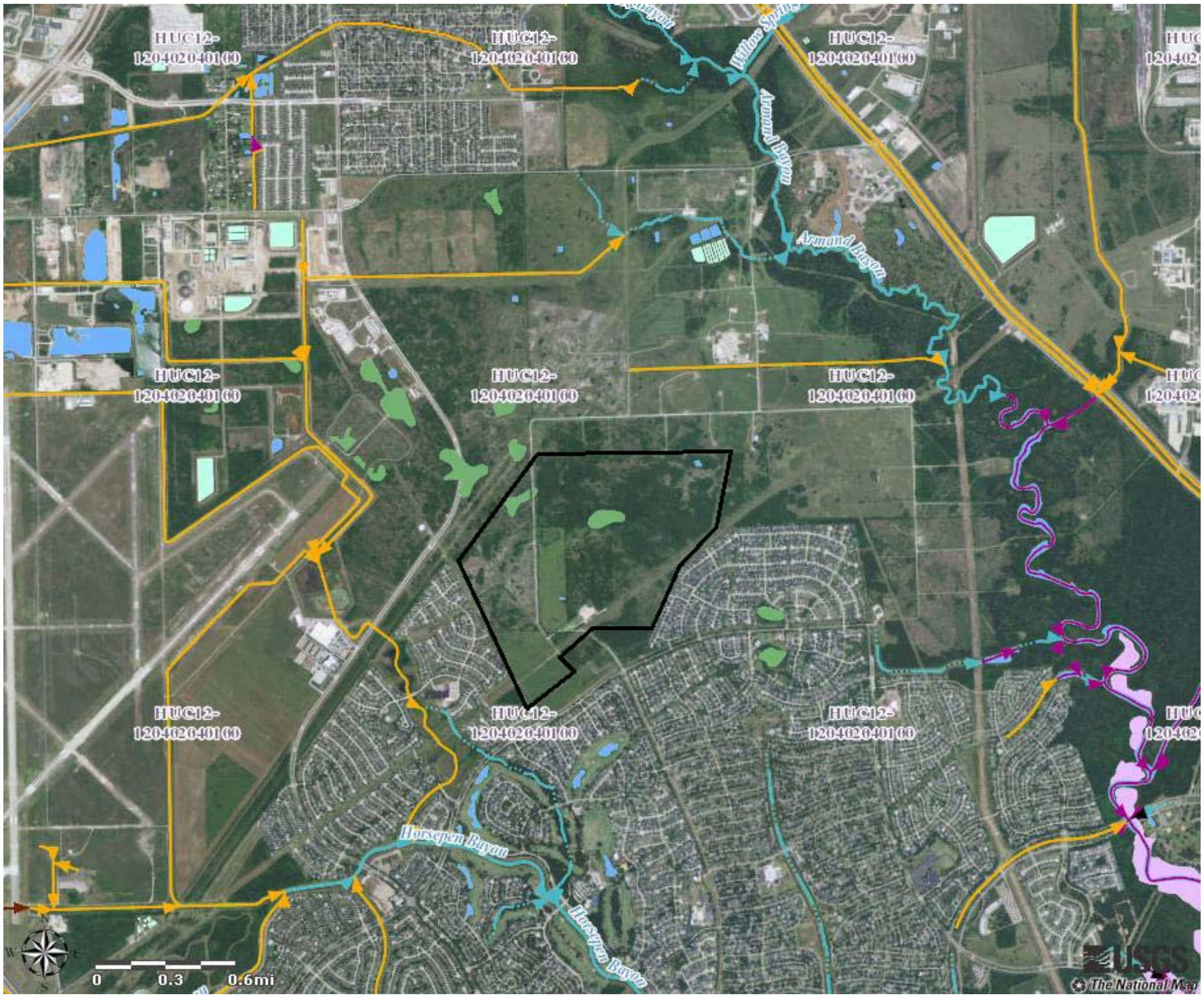

Figure 3. Map of the vicinity of the subject wetlands (bounded in black) from USGS National Hydrography Dataset, showing drainage network and flow lines. Note however, that some key drainage ditches shown in Figure 2 are not shown here.

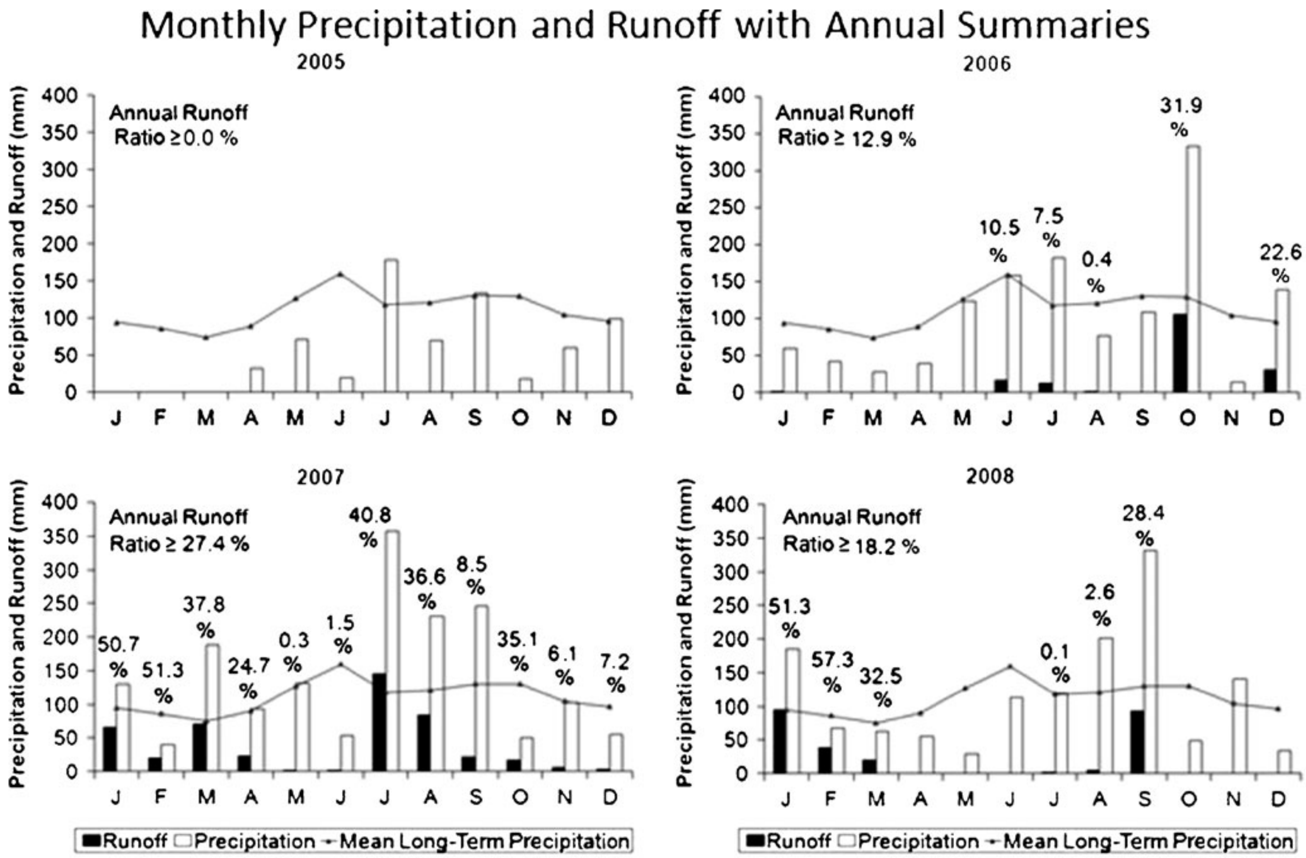

Figure 4. Monthly precipitation and runoff for a wetland site very similar to, and very near, the subject wetlands, for 2005-2008. Runoff volume is expressed as a uniform depth over the watershed (mm). The percentage of rainfall discharged as runoff is shown for each month. The line represents average precipitation since 1929, for comparison. From Wilcox et al. (2011).

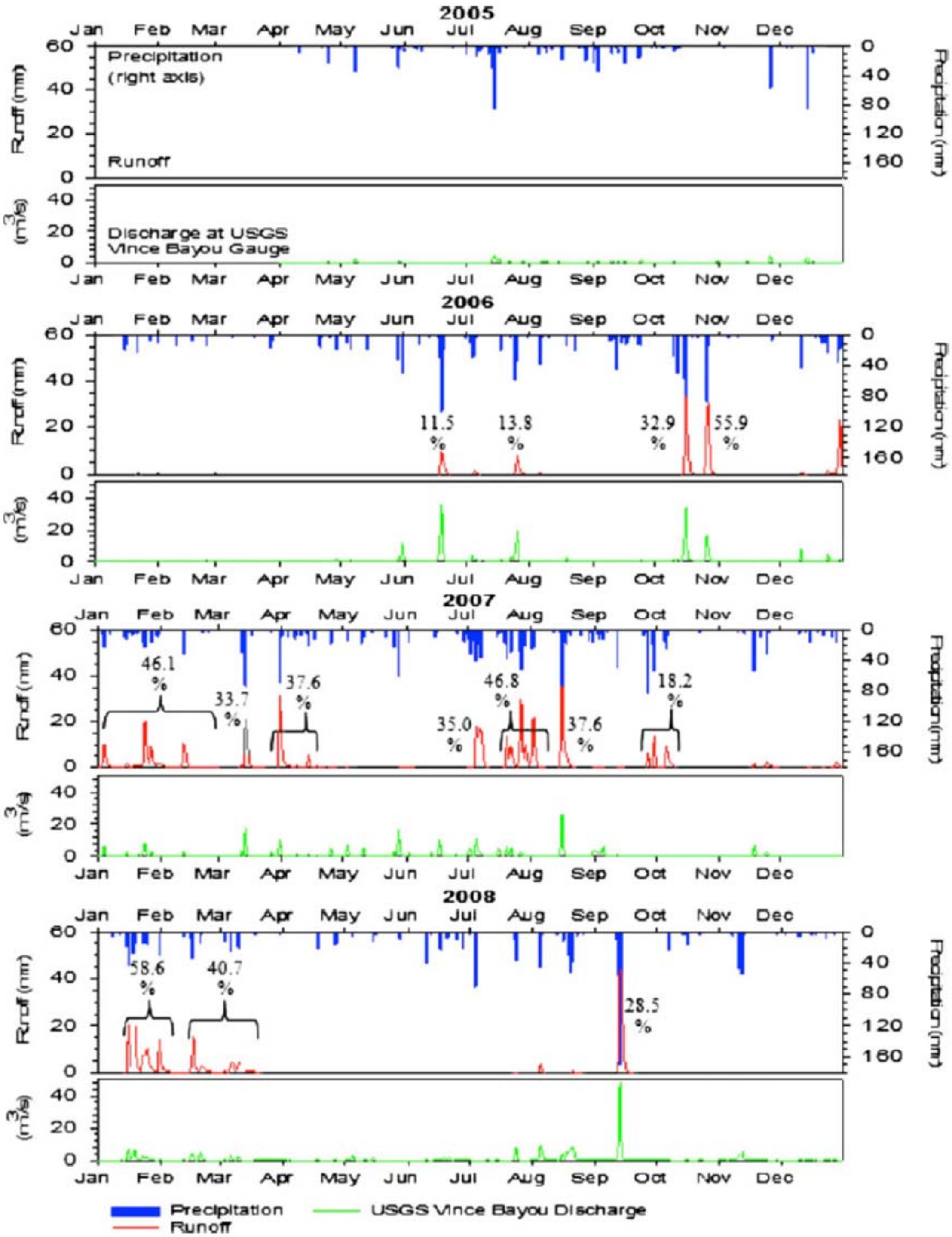

Figure 5. Annual hydrographs (2005-2007) of daily precipitation and runoff data for a very similar wetland site near the subject wetlands. Runoff percentages are given for major events, and the rate of runoff at an upstream gage is shown for each year. Even-based runoff percentages were calculated from the first precipitation event followinga a 24-hr dry period to the beginning of the first 24-hr period with no runoff. Gaps indicate no runoff or no data. From Wilcox et al. (2011).

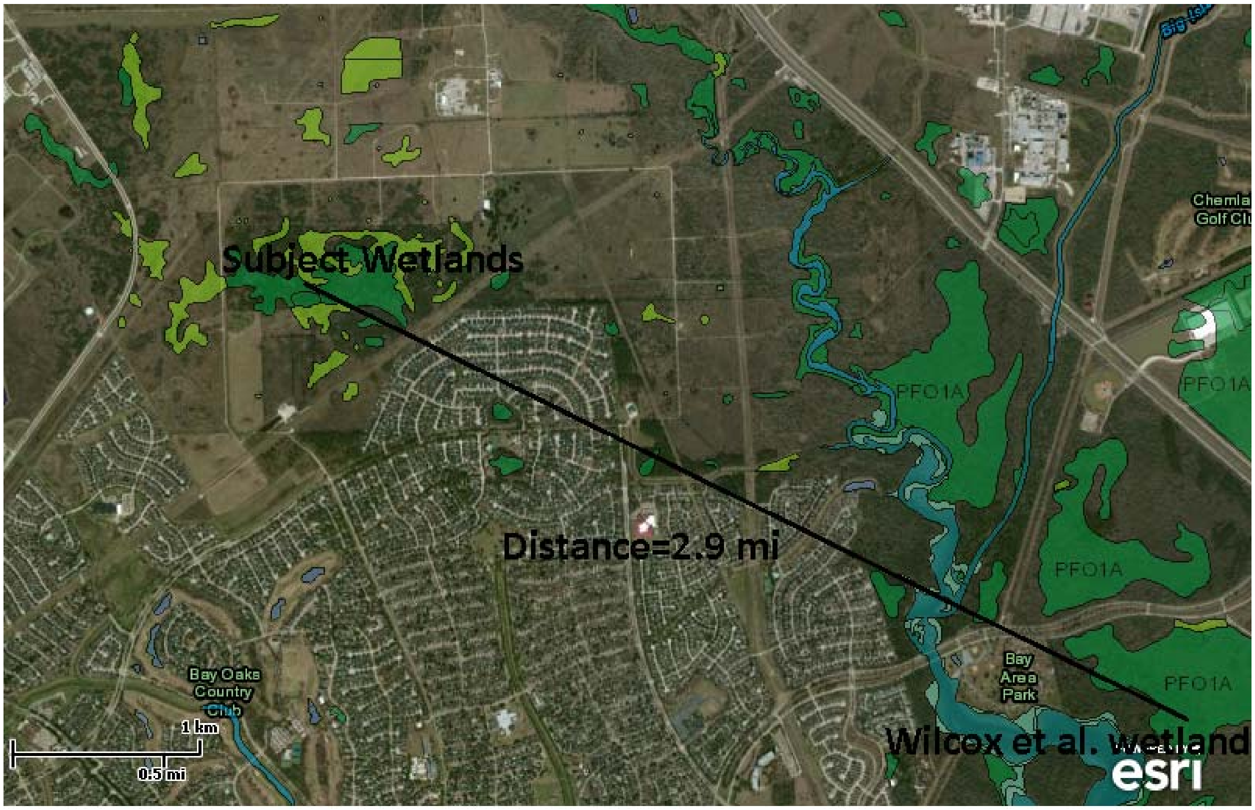

Figure 6. Map showing proximity of Wilcox et al. (2011) wetland to subject wetlands.

Teague, Kenneth

From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I think we did address these 51.

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

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This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are NOT waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

Thanks
Kenny Jaynes

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From: Jaynes, Kenneth E (Kenny) SWG
Sent: Tuesday, October 07, 2014 12:13 PM
To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

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This approximate 370 acre project area is located east of Ellington Field in League City area of Harris County, Texas. The majority of the site has been landcleared and some detention basins have been constructed. This includes an appx 30 acre tract, located south of the pipeline easement that has not been landcleared. This small portion of the site has a mix of tallow dominated areas and open herbaceous seasonal prairie and has appx. 6 wetland polygons that total an appx 1.8 acres. This entire project area historically contained mostly upland prairie with a mix of seasonal depressional wetlands (some of which were dominated with tallow trees). It has been and continues to have portions being used for graze land. The source of hydrology for the wetlands on the site is precipitation. The wetland are seasonal and depressional. The soils are mapped as clay loams and clays; thus affecting lateral movement of shallow subsurface hydrology.

Since the majority of the site has been impacted by the mechanized land-clearing much of the extents of the wetlands were based upon off-site information in conjunction with four separate field visits conducted by the Corps. (NOTEWORTHY: a previous field visit was conducted by the Corps and EPA {Jim Herrington} to investigate a purported unauthorized activity which was found to not be an unauthorized activity.) The appx. wetland polygons and sizes varied from appx. 0.02 acre to greater than appx. 7 acres (noting greater than 80% are re less than an acre in size); with an estimated aggregate total of appx. 49 acres. The distance to the nearest water of the U.S. (a RPW of Horsepen Bayou) varied from appx. 0.4 mile to greater than 1.3 miles. The appx. distances to the nearest TNW (Armand Bayou) would be appx. 1.3 miles and the furthest would be appx. 2.2 miles. The entire site was examined and based on site information and off-site information there were not any confined surface hydrologic connections nor any shallow subsurface hydrologic connections (based on sampling) detected. All of these appx. 51 wetlands are located outside the anticipated high flow (above the 100-year flood plain of any water of the U.S.). If there were ever to occur any "fill and spill" that might provide hydrology to any waters of the U.S., it would have to be through overland sheet flow, and it would be for extremely brief and episodically events that would occur in extreme above normal circumstances/conditions.

Historically, there have been concerns expressed regarding the fact that recent scientific reports revealed that isolated (as per federal regulations) depressional seasonal wetlands similar to these, provide sinks that fixate N and P and/or effect the water budget; to address this concern it is SWG position that there are numerous other factors that also play into these determinations. Therefore, based on the fact that these geographically isolated wetland that are not "inseparably bound-up" to the nearest TNW, it would be purely speculative to state that the destruction of these wetlands would have more than speculative or insubstantial effect upon the chemical, physical and/or biological integrity of the nearest TNW located greater than 1 mile away.

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These wetlands (as identified per the manual) are located outside any anticipated high flow (e.g. 100-yr floodplain) of any waters of the U.S., are surrounded by uplands, are not tidal, and are not located in an ecological landscape position that would be utilized for any known species in the geo-region that would require both the wetland and the water body to fulfill their life cycle requirements. These wetlands are located greater than a mile away from the nearest water body. There are not any surface hydrologic connections to any waters of the U.S., these wetlands are not located in a geomorphic position that is inseparably bound to any water of the U.S. nor is there any known biological species in this geo-region that requires both the wetland in review and the nearest TNW to full life cycle requirements.

Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

In conclusion, the Corps has verified that the majority of the site is uplands and there are some pockets of depressional seasonal wetlands on the tract by using on-site and off-site information per the appropriate manual. The wetlands are located in an "isolated" (as defined by federal regulation: 33 CFR 330.2 Definitions:(e) Isolated waters means those non-tidal waters of the U.S. that are:(1) Not part of a surface tributary system to interstate or navigable waters of the US; and (2) Not adjacent to such tributary waterbodies). There is no known nexus to interstate commerce associated with any of them. As such, it is the Corps draft determination that these wetlands would not be subject to federal jurisdiction under Section 404 of the Clean Water Act. Noting as of the date of this e-mail much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

Kenny Jaynes
SWG POC

Teague, Kenneth

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Sent: Thursday, October 09, 2014 1:57 PM
To: Parrish, Sharon
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I'm working on the 2 JDs.

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:56 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

Have we responded to these?

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Sent: Tuesday, October 07, 2014 12:13 PM
To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
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Kenny Jaynes
SWG POC

Teague, Kenneth

From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

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From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

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To: Isolated Waters; Parrish, Sharon
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Kenny Jaynes
SWG POC

Teague, Kenneth

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Sent: Thursday, October 09, 2014 1:59 PM
To: Parrish, Sharon
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Actually, I'm working on 2 others. These, I have not yet seen.

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These wetlands (as identified per the manual) are located outside any anticipated high flow (e.g. 100-yr floodplain) of any waters of the U.S., are surrounded by uplands, are not tidal, and are not located in an ecological landscape position that would be utilized for any known species in the geo-region that would require both the wetland and the water body to fulfill their life cycle requirements. These wetlands are located greater than a mile away from the nearest water body. There are not any surface hydrologic connections to any waters of the U.S., these wetlands are not located in a geomorphic position that is inseparably bound to any water of the U.S. nor is there any known biological species in this geo-region that requires both the wetland in review and the nearest TNW to full life cycle requirements.

Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

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Kenny Jaynes
SWG POC

Teague, Kenneth

From: Teague, Kenneth
Sent: Thursday, October 09, 2014 1:59 PM
To: Parrish, Sharon
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

We have a little time to respond though.

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I think we did address these 51.

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From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

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Kenny Jaynes

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To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

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Kenny Jaynes
SWG POC

Teague, Kenneth

From: Teague, Kenneth
Sent: Thursday, October 09, 2014 2:00 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

fyi

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Sent: Tuesday, October 07, 2014 12:31 PM
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Kenny Jaynes
SWG POC

SP-381
4-11

Texas Coastal Watershed Program

Texas Sea Grant and Texas AgriLife Extension

Texas A&M University System

Upper Texas Gulf Coast Pothole Wetlands:

New Research shows Significant and Profound Hydrologic Connections to Galveston Bay and other Area Waters

Issue: After the 2001 Supreme Court SWANCC decision, the US Army Corp of Engineers (USACE) Galveston District ceased jurisdiction over a class of wetlands referred to variously as coastal prairie or forested potholes, coastal depressions, coastal prairie potholes, etc. Wetlands not in the 100-yr floodplain and without a bed and banks connection to a waters of the U.S. were presumed to be hydrologically-isolated, closed depressions with no surface connection to waters of the US. Hundreds of thousands of acres of coastal pothole wetlands (CPW) on the Pleistocene and Lissie-aged geologic formations fell out of jurisdiction. Since 2001, losses of these wetlands to development have not been mitigated. Coastal Pothole Wetlands comprise the vast majority of wetlands lost to development on the Upper Gulf Coast of Texas. In Harris County alone, some 30% of all freshwater wetlands extant in 1992 were lost to development by 2008 (unpublished research, Texas A&M University, Texas Coastal Watershed Program).

Most of the wetland experts in the region believed CPW to be hydrologically connected to waters of the U.S., based on informal field observations over several years, but until recently there was no quantitative data to back up these observations. The 2007 Supreme Court Rapanos decision reaffirmed the long-standing legal concept of a “significant nexus” in determining jurisdictionality of potentially isolated wetlands. Justice Kennedy, in his “hinge” opinion of the Rapanos 4-1-4 split, declared that a significant nexus to a water of the U.S. could be determined for a class of wetlands, such that a full determination of that issue would not be needed for every wetland in that class. The Kennedy opinion has become *de facto* if not *de jure* guidance for Corps field offices. The studies reported here quantitatively demonstrate such a nexus for a broad class of wetlands on the Upper Texas Gulf Coast, and confirm long standing field observations.

Two New Studies

Two recently completed independent studies demonstrate that the coastal pothole wetlands of the Lissie and Beaumont Geologic Formations on the Upper Texas Gulf Coast have significant

John S. Jacob
Professor and Extension Specialist
Department of Recreation, Parks and Tourism Sciences
March 2011

and persistent hydrologic connections to waters of the US through a continuous wetland network of swales and poorly-defined concentrated flow paths. The two studies, listed below, used different but complementary methodologies to arrive at remarkably similar conclusions.

Forbes, M., R. Doyle, A. Clapp, J. Yelderman, N. Enwright, and B. Hunter. 2010. Final Report. Freshwater Wetland Functional Assessment Study. *Contract No. 582-7-77820.* Galveston Bay Estuary Program and Texas Commission on Environmental Quality.

Wilcox, B.P., D.D. Dean, J.S. Jacob, and A. Sipocz. 2011. Evidence of surface connectivity for Texas Gulf Coast depressional wetlands. Wetlands 31:451-458. DOI 10.1007/s13157-011-0163-x

The Forbes study looked at 6 wetland sites for 18 months and an additional 6 sites for 7 months. From their study: *Despite drought conditions for much of the study, all six wetlands overflowed during the monitoring period. The average duration of outflow was 27 days. On a volume basis, the six wetlands stored an average of 82% of incoming water and discharged 18%. Patterns of storage and discharge were strongly influenced by antecedent moisture conditions. These results, combined with the preliminary water level data from six additional CPWs, indicate that discharge appears to be a regular feature of most CPWs* (coastal prairie wetlands). Outflow from the first six wetland sites ranged from 7 to 28% of the total inflow.

The Wilcox study examined one wetland in detail over a 45 month period, measuring discharge directly. From the Wilcox study: *The results of this study indicate that surface runoff, although intermittent, occurred regularly and accounted for more than 17% of precipitation over the 45 months, with annual discharge ranging from 0% to 27%.*

In both studies, discharge from the wetlands was documented even in drier-than-normal years In both studies runoff from CPW is episodic, but can occur continuously for significant periods, ranging from 4 to 68 days and averaging 17 days in the Wilcox study. A similar range was observed in the Forbes study, where 3 months was the longest continuous period of runoff from a wetland.

The Wilcox study specifically measured runoff flowing through poorly-defined concentrated flow paths connecting pothole depressions to a well-defined water of the US. These swales had all 3 jurisdictional wetland parameters but did not meet the traditional bed and banks definition.

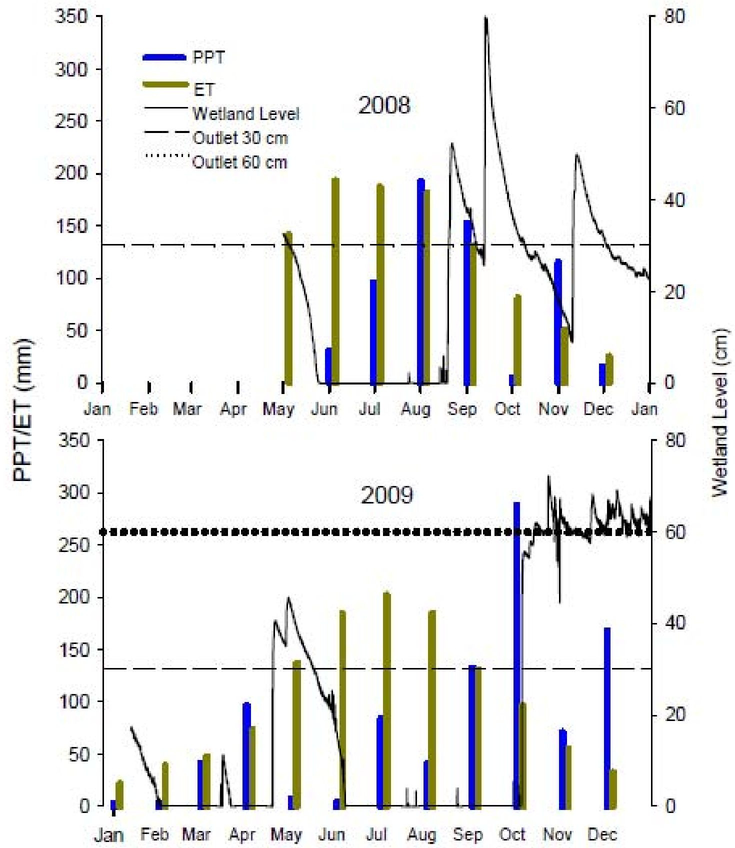
An important conclusion from both studies is that most if not all surface runoff from natural and farmed areas entering Galveston Bay and other waters passes through coastal pothole wetlands. This conclusion from the Wilcox study is relevant to both studies: [These] *findings provide strong evidence that shallow wetland depressions on the Texas coastal plain are not closed systems. Whenever their storage capacity is exceeded, they discharge excess water downslope, and their discharge can account for a significant portion of the annual water budget. Given the well documented water quality cleansing functions of wetlands , there can be little question that* [coastal pothole wetlands] *on the Upper Texas Gulf Coast contribute to the aquatic integrity* [of downstream water bodies].

The Forbes study specifically documented the water quality functions of coastal prairie pothole wetlands on the Upper Gulf Coast of Texas. Given the degraded water quality of water bodies in this area, we now have a much clearer picture of the important role these wetlands play in this area.

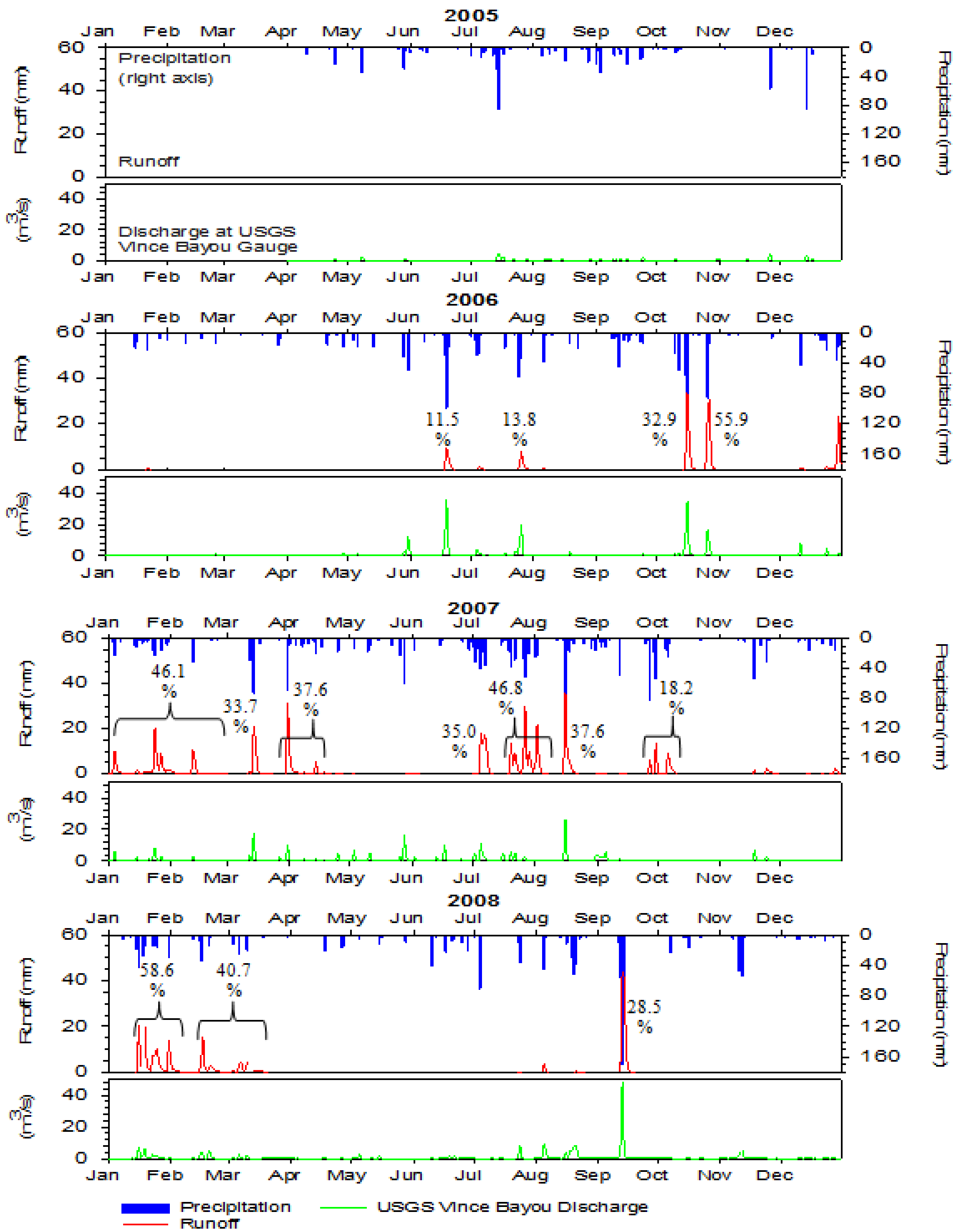
Significance

1. Coastal pothole wetlands on the Upper Texas Gulf Coast are not isolated in the sense of no hydrologic overflow. These depressions are frequently overtopped, even in dry years.
2. Overflow from these wetlands is entrained in a series of swales or somewhat poorly-defined flow paths with wetland characteristics that naturally or through imposed artificial drainage connect to waters of the U.S.
3. Because most surficial runoff in natural or farmed areas courses through CPW, these wetlands are a critical part of the aquatic integrity of our regional bayous and bays that constitute waters of the US.
4. In light of the documentary evidence that CPW on the Upper Texas Gulf Coast meet the significant nexus criteria outlined by Justice Kennedy in the Rapanos decision, this class of wetlands should therefore be considered jurisdictional unless isolation can be quantitatively demonstrated.

Figures



Hydrograph for 2008-9 for the Forbes study Chicken Road site. Discharge from this wetland constituted 23% of the inflow.



Hydrograph for the Armand Bayou Site of the Wilcox Study. Percentages are runoff volumes of the associated precipitation events.

Forbes Wounded Dove Site and Chicken Road sites. Notice continuous wetland swales connecting WD to the CR Swale which is connected to Bastrop Bayou. These depression are relict Pleistocene or early Holocene channels. Yellow scale bar is 2000 ft.

Classic prairie pothole topography near Damon. Notice virtually continuous network of potholes and swales connecting to natural or artificial drainage network. One of many potential flow paths shown: w=wetland, D=drain, arrows are poorly to moderately defined flow paths

Similar network adjacent to Hwy 146 in the League City area.

area are wind-generated tides, which affect most bay and lagoon environments and have produced wind-tidal flats and marshes (discussed in the wetlands section, p. 65). Other processes affecting environments in the bays and along the inner shelf are listed in table 1.

Active processes are integral components of the natural systems that have operated along the coast during the Pleistocene and Holocene epochs. These natural systems (fig. 9), defined and mapped by Fisher and others (1972), reflect natural and genetic associations and include (1) the offshore system, consisting of the inner continental shelf and the barrier-island shoreface located seaward of the Gulf beaches, (2) the barrier-strandplain system, consisting of the modern barrier islands and the Pleistocene barrier strandplains, (3) the bay-estuary-lagoon system, consisting of submerged estuarine environments, (4) the fluvial-deltaic system, consisting of the relict and modern environments formed by ancient (Pleistocene) and modern rivers and deltas, and (5) the marsh-swamp system, consisting of the various permanently to intermittently wet environments occurring both in low-lying coastal areas and in association with most of the above-mentioned systems. Natural systems in the Galveston-Houston area are discussed in a later section of this report (p. 68) in conjunction with wetlands, and a more in-depth discussion is presented by Fisher and others (1972).

BATHYMETRY

Bathymetry is an important parameter because it commonly controls the distribution of sediment textures, sediment geochemistry, and benthic macroinvertebrates. Sounding data, from which bathymetric maps of the bay-estuary-lagoon system were prepared (pl. V), were collected during the sampling phase of the program by measuring water depth at each sample station (depths are not adjusted to sea-level datum). Bathymetry of the inner shelf (pl. V) was derived from maps published by the National Ocean Survey (McGowen and Morton, 1979).

Galveston Bay—the deepest bay in the system—is 10 to 12 ft (3 to 3.7 m) deep over most of the bay area. Depths in Trinity, East, and West Bays are less than in Galveston Bay; bay centers are approximately 8 ft (2.4 m), 4 to 8 ft (1.2 to 2.4 m), and 4 to 6 ft (1.2 to 1.8 m) deep, respectively. Depths in parts of East Bay and central Galveston Bay are variable because of the presence of oyster reefs, over which resulting shallower water occurs.

Shallow bays, those with depths of generally less than 4 ft (1.2 m), include Chocolate, Christmas, Bastrop, Jones, Dickinson, Dollar, and Tabbs Bays and Clear and Moses Lakes. The deepest parts of the bay-estuary-lagoon system are the dredged ship channels where dredged depths are nearly 45 ft (13.6 m). The Houston Ship Channel, which is 41 ft (12.5 m) deep, crosses lower and upper Galveston Bays and has branches extending to the city of Galveston and Texas City. The Intracoastal Waterway is approximately 12 ft (3.7 m) deep and crosses lower Galveston Bay.

The shelf slope near the Gulf shoreline is relatively steep (approximately 24 ft/mi, or 4.5 m/km). Gentler slopes are found beyond a distance of about 1 mi (1.6 km) offshore. At approximately 10 mi (16 km) offshore, the slope decreases to about 1 to 2 ft/mi (0.2 to 0.4 m/km), and depths along the southern edge of the map sheet area exceed 60 ft (18.3 m) (pl. V).

SALINITY

Salinity is an important parameter because it affects the distribution of marsh vegetation and the distribution of benthic macroinvertebrates. Water salinities in the bay-estuary-lagoon system in the Galveston-Houston area vary across the entire system, in part because of regional variations caused by fresh-water inflows from rivers and streams and by salt-water interchange from tidal passes (San Luis Pass, Bolivar Roads, and Rollover Pass). Compounding the complexity of the bay-estuary-lagoon system are seasonal and cyclic climatic variations that produce substantially higher than normal salinities during dry periods and lower than normal salinities during wet periods.

Salinity data were not collected during the sampling phase of the submerged lands project. Salinities reported by the Texas Parks and Wildlife Department (Martinez, 1973, 1974, 1975) in the Galveston Bay system (including Trinity, East, and West Bays) provide some salinity data for the 1970's. Sediment samples were collected in the Galveston-Houston area in 1976 and 1977.

Salinities are generally highest in West Bay, followed, in order of decreasing average salinity, by Galveston, East, and Trinity Bays (fig. 10). Average salinities in West Bay are generally more than 15 parts per thousand (ppt) and range into the 30's, which is in marked contrast to Trinity Bay,

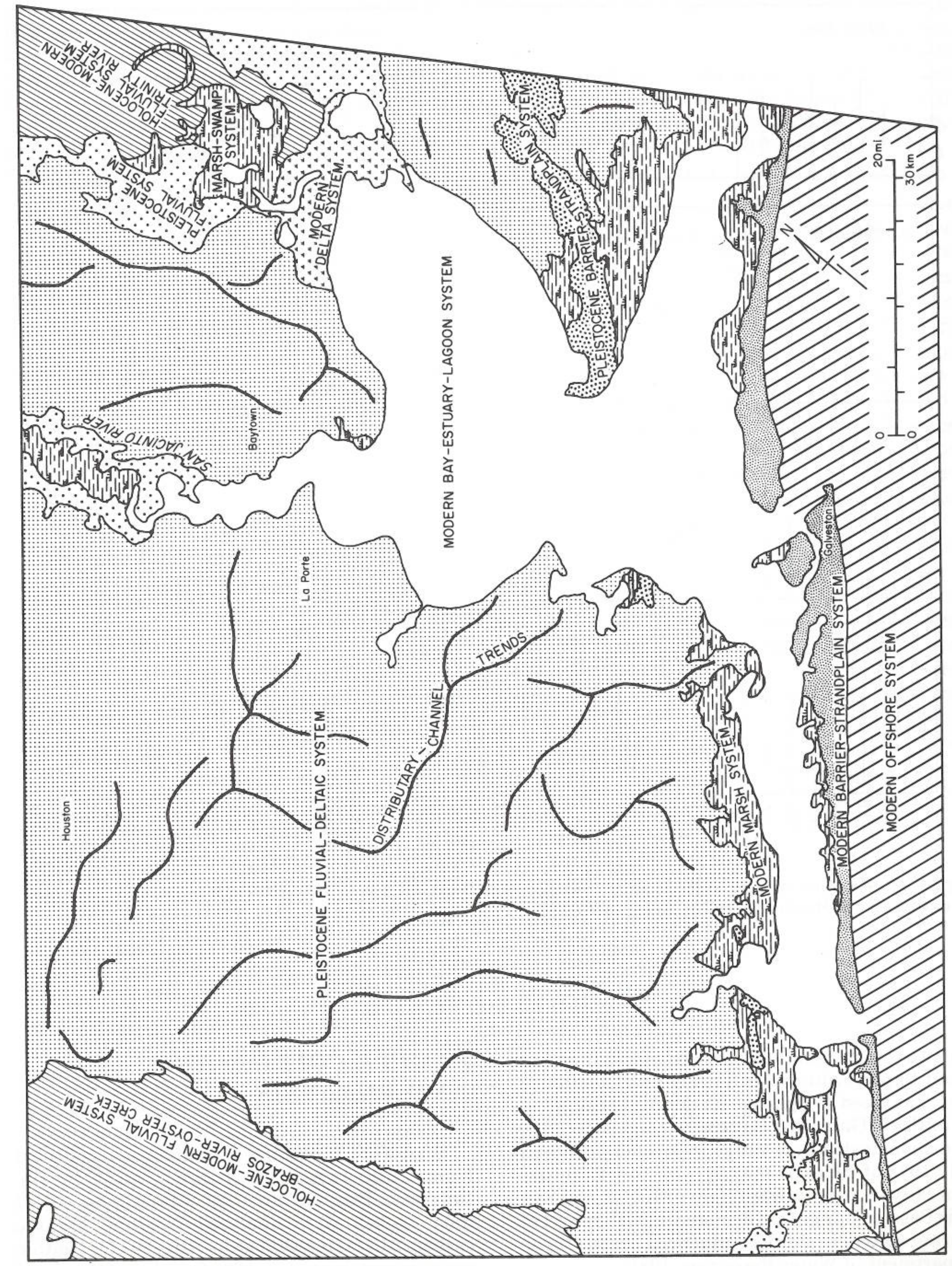


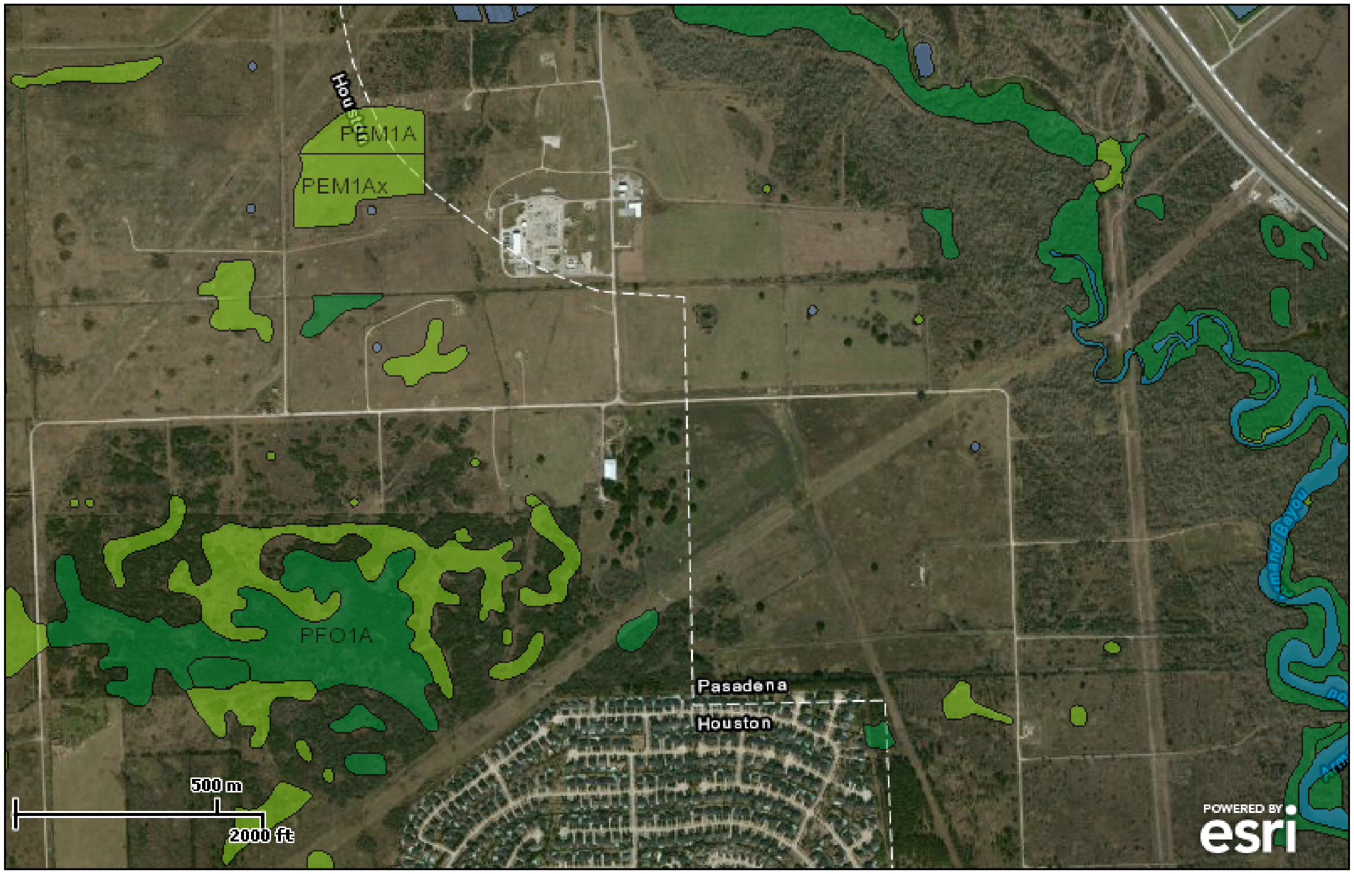
Figure 9. **Natural systems of the Galveston-Houston area (from Fisher and others [1972]).**

U.S. Fish and Wildlife Service

National Wetlands Inventory

JD
SWG-2013-00982

Oct 22, 2014



Wetlands

- Freshwater Emergent
- Freshwater Forested/Shrub
- Estuarine and Marine Deepwater
- Estuarine and Marine
- Freshwater Pond
- Lake
- Riverine
- Other

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

User Remarks:

U.S. Fish and Wildlife Service

National Wetlands Inventory

JD
SWG-2013-00982

Nov 13, 2014

Wetlands

- Freshwater Emergent
- Freshwater Forested/Shrub
- Estuarine and Marine Deepwater
- Estuarine and Marine
- Freshwater Pond
- Lake
- Riverine
- Other

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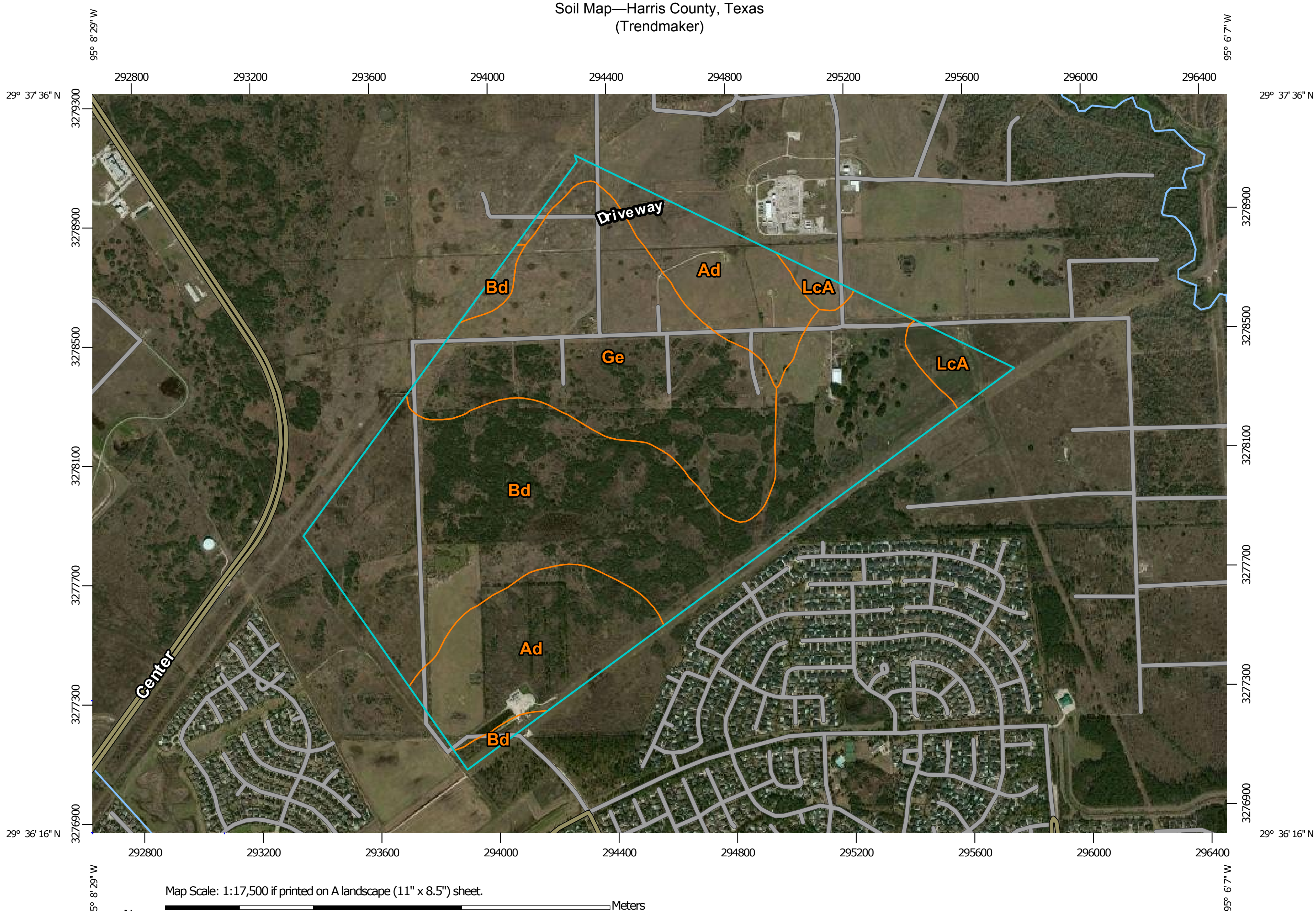
User Remarks:

Soil Map—Harris County, Texas
(Trendmaker)



Map Scale: 1:17,500 if printed on A landscape (11" x 8.5") sheet.

N

0 250 500 1000 1500 Meters

0 500 1000 2000 3000 Feet

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 15N WGS84

MAP LEGEND

Area of Interest (AOI)
Area of Interest (AOI)

Soils
Soil Map Unit Polygons
Soil Map Unit Lines
Soil Map Unit Points

Special Point Features
Blowout
Borrow Pit
Clay Spot
Closed Depression
Gravel Pit
Gravelly Spot
Landfill
Lava Flow
Marsh or swamp
Mine or Quarry
Miscellaneous Water
Perennial Water
Rock Outcrop
Saline Spot
Sandy Spot
Severely Eroded Spot
Sinkhole
Slide or Slip
Sodic Spot
Spoil Area
Stony Spot
Very Stony Spot
Wet Spot
Other
Special Line Features

Water Features
Streams and Canals

Transportation
Rails
Interstate Highways
US Routes
Major Roads
Local Roads

Background
Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Harris County, Texas
Survey Area Data: Version 14, Sep 30, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jan 26, 2011—Mar 6, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Harris County, Texas (TX201)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Ad	Addicks loam	124.9	21.4%
Bd	Bernard clay loam	279.8	47.9%
Ge	Gessner fine sandy loam, 0 to 1 percent slopes, ponded	161.7	27.7%
LcA	Lake Charles clay, 0 to 1 percent slopes	17.6	3.0%
Totals for Area of Interest		**583.9**	**100.0%**

NOTES TO USERS

is for use in administering the National Flood Insurance Program. It necessarily identify all areas subject to flooding, particularly from local sources of small size. The **community map repository** should be for possible updated or additional flood hazard information.

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erence System Division
eodetic Survey, NOAA
ng Metro Center
West Highway
ng, Maryland 20910
3242

urrent elevation, description, and/or location information for **bench marks** this map, please contact the Information Services Branch of the Geodetic Survey at **(301) 713-3242,** or visit their website at noaa.gov.

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0-358-9616
358-9620
a.gov/msc

ve **questions about this map** or questions concerning the National rance Program in general, please call **1-877-FEMA-MAP** (1-877-336- sit the FEMA website at www.fema.gov.

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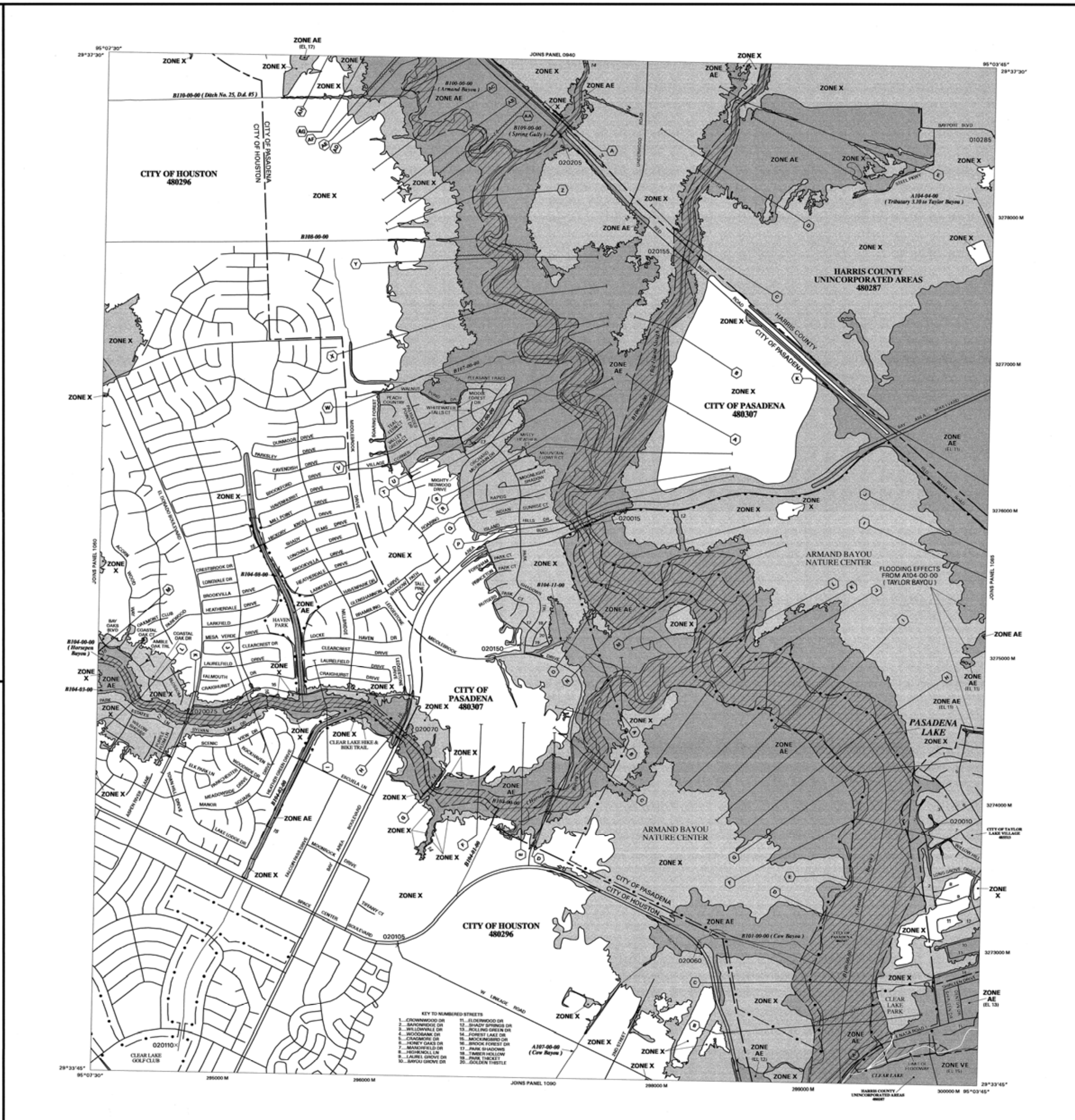

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INU BY THE 1% ANNUAL CHANCE FLOOD EVENT

The 1% annual chance flood (100-year flood), also known as the base flood that has a 1% chance of being equaled or exceeded in any given year. Flood Hazard Area is the area subject to flooding by the 1% annual chance of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and Flood Elevation is the water surface elevation of the 1% annual chance flood.

ZONE A	No base flood elevations determined.
ZONE AE	Base flood elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on slo average depths determined. For areas of alluvial fan floodin also determined.
ZONE AR	Area of special flood hazard formerly protected from the chance flood event by a flood control system that was decertified. Zone AR indicates that the former flood contr being restored to provide protection from the 1% annua greater flood event.
ZONE A99	Area to be protected from 1% annual chance flood event flood protection system under construction; no base floo determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); base flo determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas kept free of encroachment so that the 1% annual chance flood can be ca substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual with average depths of less than 1 foot or with drainage ar 1 square mile; and areas protected by levees from 1% an flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplai
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) A

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Haza

	Floodplain boundary
	Floodway boundary
	Zone D boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Areas Base Flood Elevations, flood depths or velocities.
513	Base Flood Elevation line and value; elevation in fee
(EL 987)	Base Flood Elevation value where uniform elevation in feet*

*Referenced to the North American Vertical Datum of 1988

(A)———(A)	Cross Section Line
(23)- - - - -(23)	Transect Line
97°07'30", 32°22'30"	Geographic coordinates referenced to the Nor Datum of 1983 (NAD 83)
4276000M	1000-meter Universal Transverse Mercator grid val
600000 FT	5000-foot grid ticks
DX5510×	Bench mark (see explanation in Notes to User this FIRM panel).
• M1.5	River Mile

MAP REPOSITORY
Refer to Repository Listing on Index Map

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
SEPTEMBER 28, 1990

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

SEPTEMBER 30, 1992
NOVEMBER 6, 1996
APRIL 20, 2000
JUNE 18, 2007: to change base flood elevations, to add special areas, to change special flood hazard areas, to change zone desig reflect updated topographic information, and to change floodway.

For community map revision history prior to countywide mapping, refer to the Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact yo agent or call the National Flood Insurance Program at (800) 638-6620.

MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

300 0 300 600 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1080L

FIRM
FLOOD INSURANCE RATE
HARRIS COUNTY,
TEXAS
AND INCORPORATED AR

PANEL 1080 OF 1150

(SEE MAP INDEX FOR FIRM PANEL

CONTAINS:

COMMUNITY	NUMBER	PANE
PASADENA, CITY OF	480307	1080
HOUSTON, CITY OF	480296	1080
TAYLOR LAKE VILLAGE, CITY OF	485515	1080
HARRIS COUNTY, UNINCORPORATED AREAS	480287	1080

Notice to User: The **Map Number** shown below when placing map orders; the **Community N** above should be used on insurance applications community.

MAP N
4820

MAP R
JUNE

Federal Emergency Managemen

NOTES TO USERS

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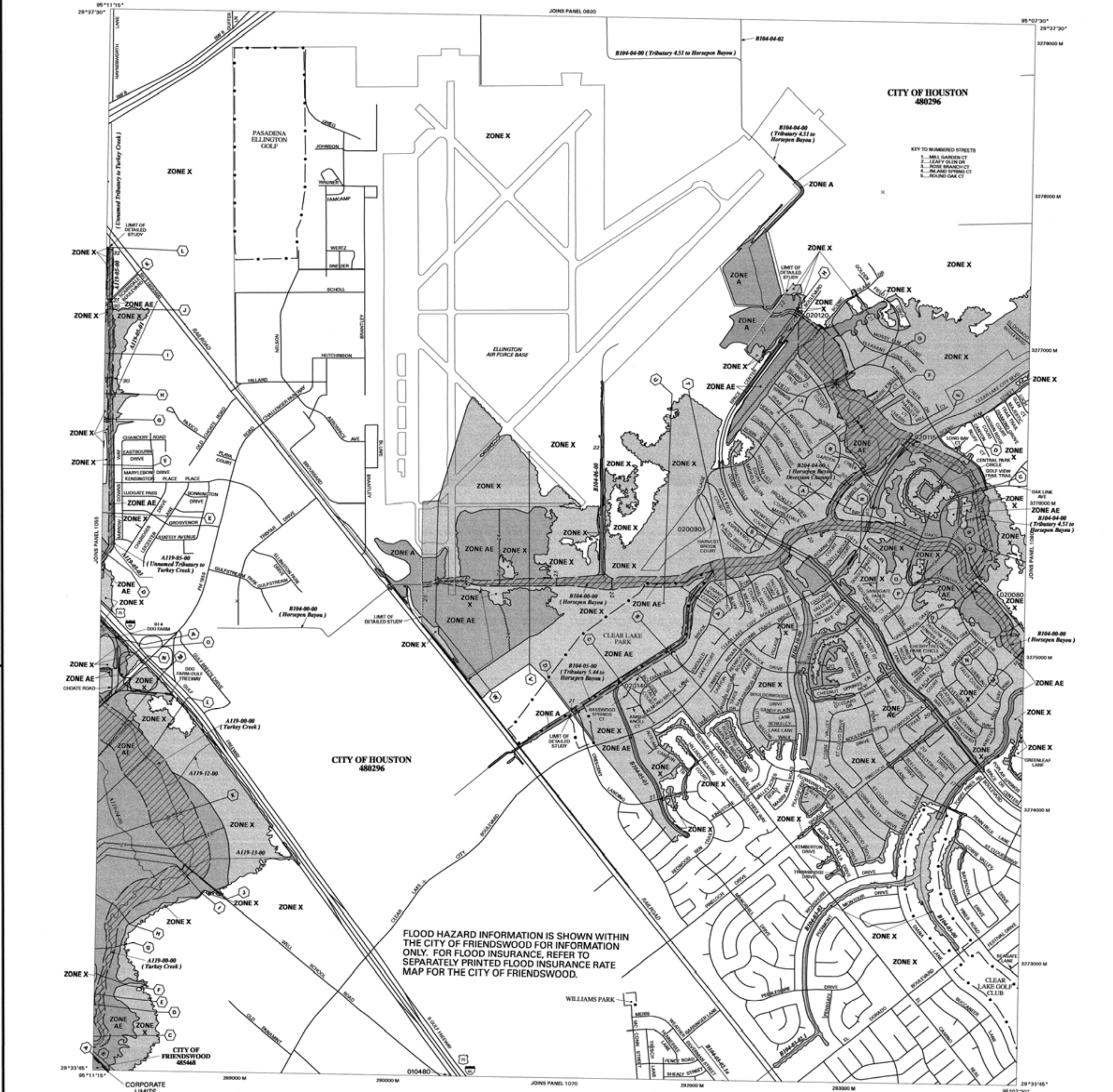

LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INU
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500 0 1000 2000 FEET

300 0 300 600 METER

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1060L

FIRM
FLOOD INSURANCE RATE

HARRIS COUNTY,
TEXAS
AND INCORPORATED AR

PANEL 1060 OF 1150

(SEE MAP INDEX FOR FIRM PANEL

CONTAINS:

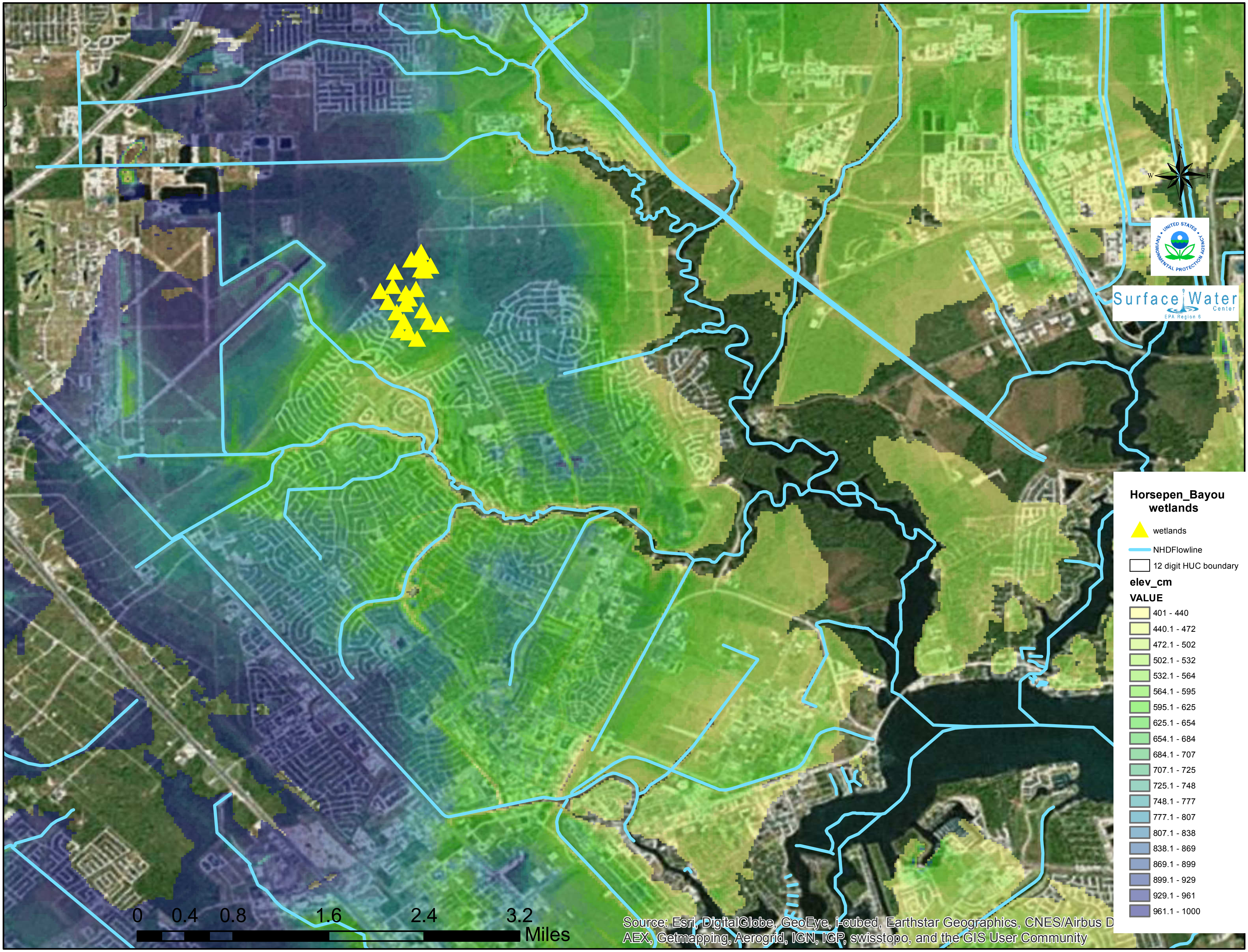
COMMUNITY	NUMBER	PAN
HOUSTON, CITY OF	480296	1060

Notice to User: The **Map Number** shown below when placing map orders; the **Community** above should be used on insurance applications community.

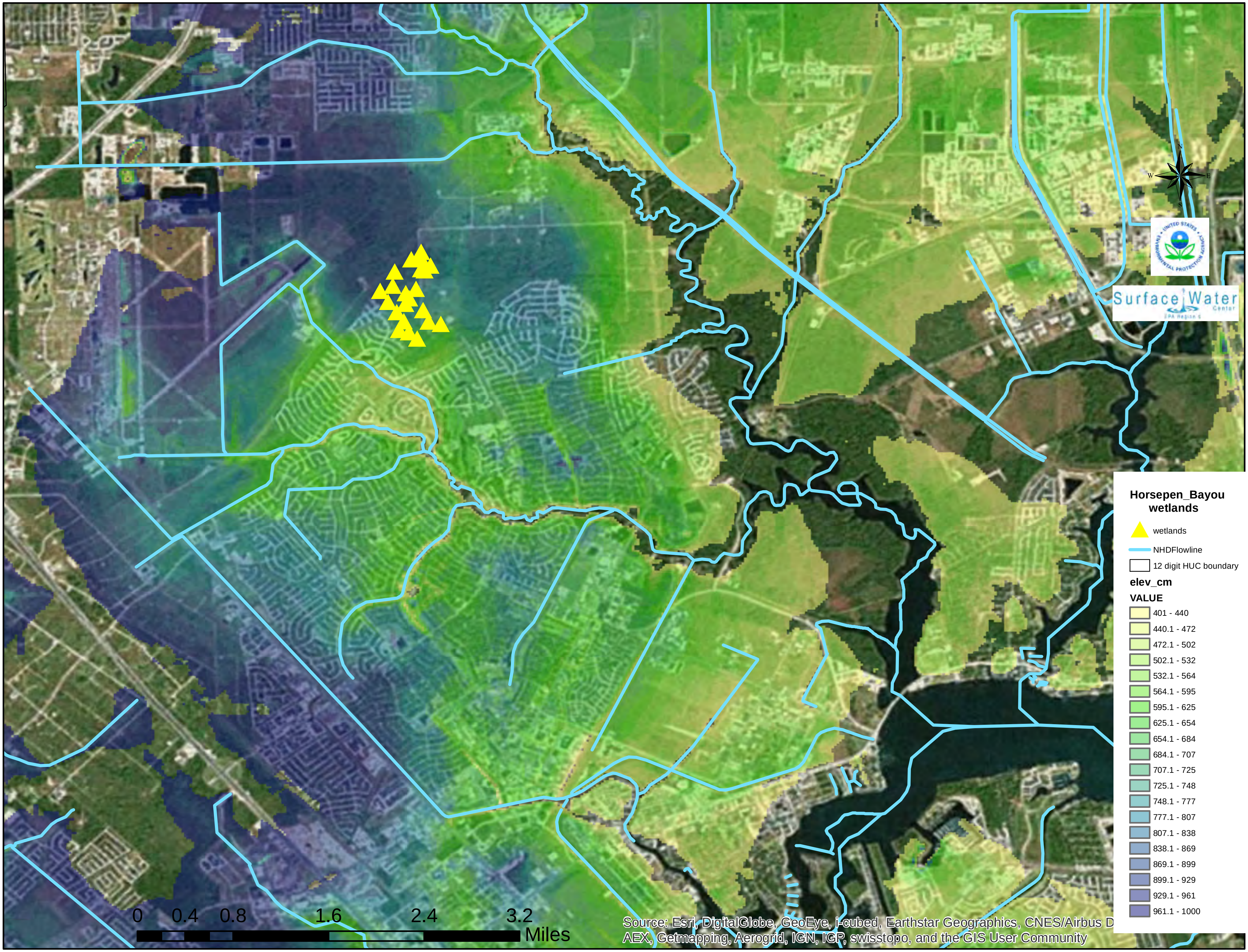
MAP
4820

MAP R
JUNE

Federal Emergency Manageme



Horsepen_Bayou wetlands
wetlands
NHDFlowline
12 digit HUC boundary
elev_cm
VALUE
401 - 440
440.1 - 472
472.1 - 502
502.1 - 532
532.1 - 564
564.1 - 595
595.1 - 625
625.1 - 654
654.1 - 684
684.1 - 707
707.1 - 725
725.1 - 748
748.1 - 777
777.1 - 807
807.1 - 838
838.1 - 869
869.1 - 899
899.1 - 929
929.1 - 961
961.1 - 1000
Surface Water Center
EPA Region 6
0 0.4 0.8 1.6 2.4 3.2
Miles
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus D
AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community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654.1 - 684
684.1 - 707
707.1 - 725
725.1 - 748
748.1 - 777
777.1 - 807
807.1 - 838
838.1 - 869
869.1 - 899
899.1 - 929
929.1 - 961
961.1 - 1000
Surface Water Center
0 0.4 0.8 1.6 2.4 3.2 Miles
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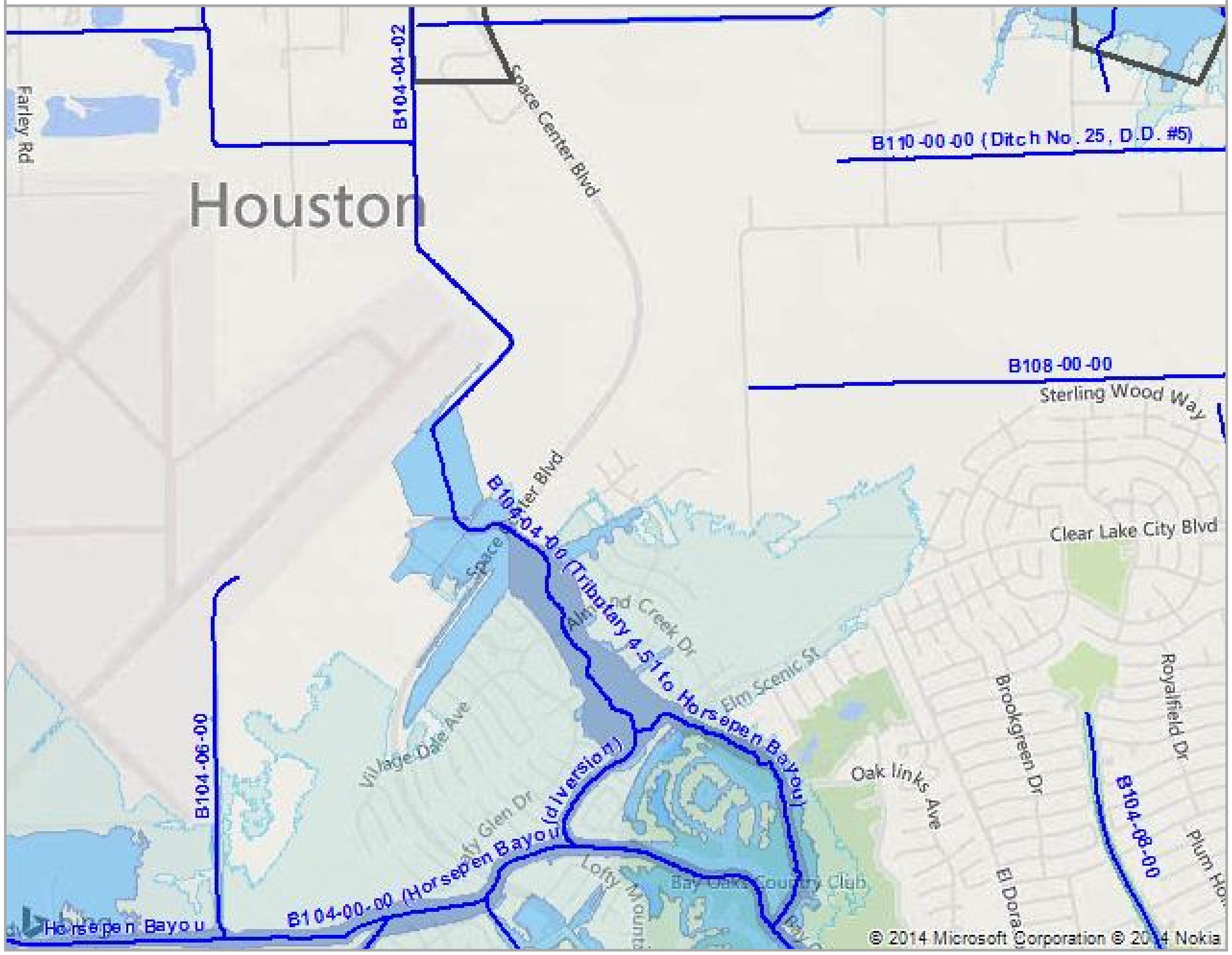
Flood Education Mapping Tool



LEGEND

- Floodway
- 1% (100-year) Floodplain
- 0.2% (500-year) Floodplain
- 1% (100-year) Coastal Floodplain
- LOMR Boundary
- Open Channels
- Enclosed Channels
- Harris County Boundary

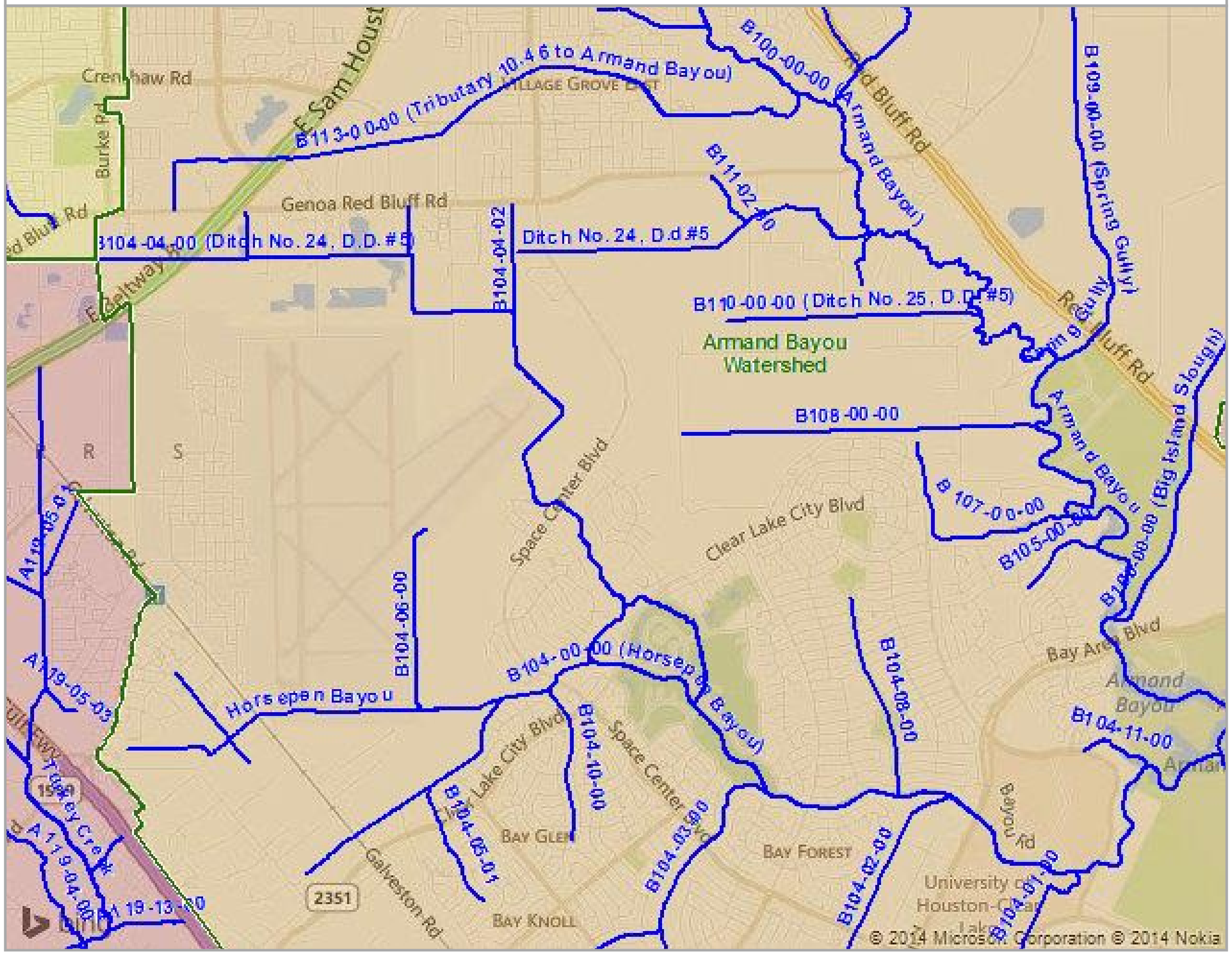
N

1 in = 2616 ft

(1 : 31396.18)

DISCLAIMER: The Harris County Flood Control District's Flood Education Mapping Tool is for general information purposes only and may not be suitable for legal, engineering or surveying purposes. The floodplains shown on this mapping tool are those delineated on the Federal Emergency Management Agency's (FEMA) effective Flood Insurance Rate Map (FIRM or floodplain map) for Harris County that was adopted in 2007, as well as updates that have been made through a Letter of Map Revision (LOMR) since 2007. This mapping tool is not an effective FIRM. The effective FIRM is produced, maintained and published by FEMA and not by the Harris County Flood Control District. Please visit FEMA's Map Service Center at www.msc.fema.gov to view the effective FIRM for Harris County. For an official floodplain determination, please contact an insurance agent or mortgage lender.This map is a representation and approximation of the relative location of geographic information, land marks and physical addresses.

Flood Education Mapping Tool



LEGEND

- Watersheds (color-coded)
- Open Channels
- Enclosed Channels
- Watershed Boundaries
- Harris County Boundary

N

1 in = 5233 ft

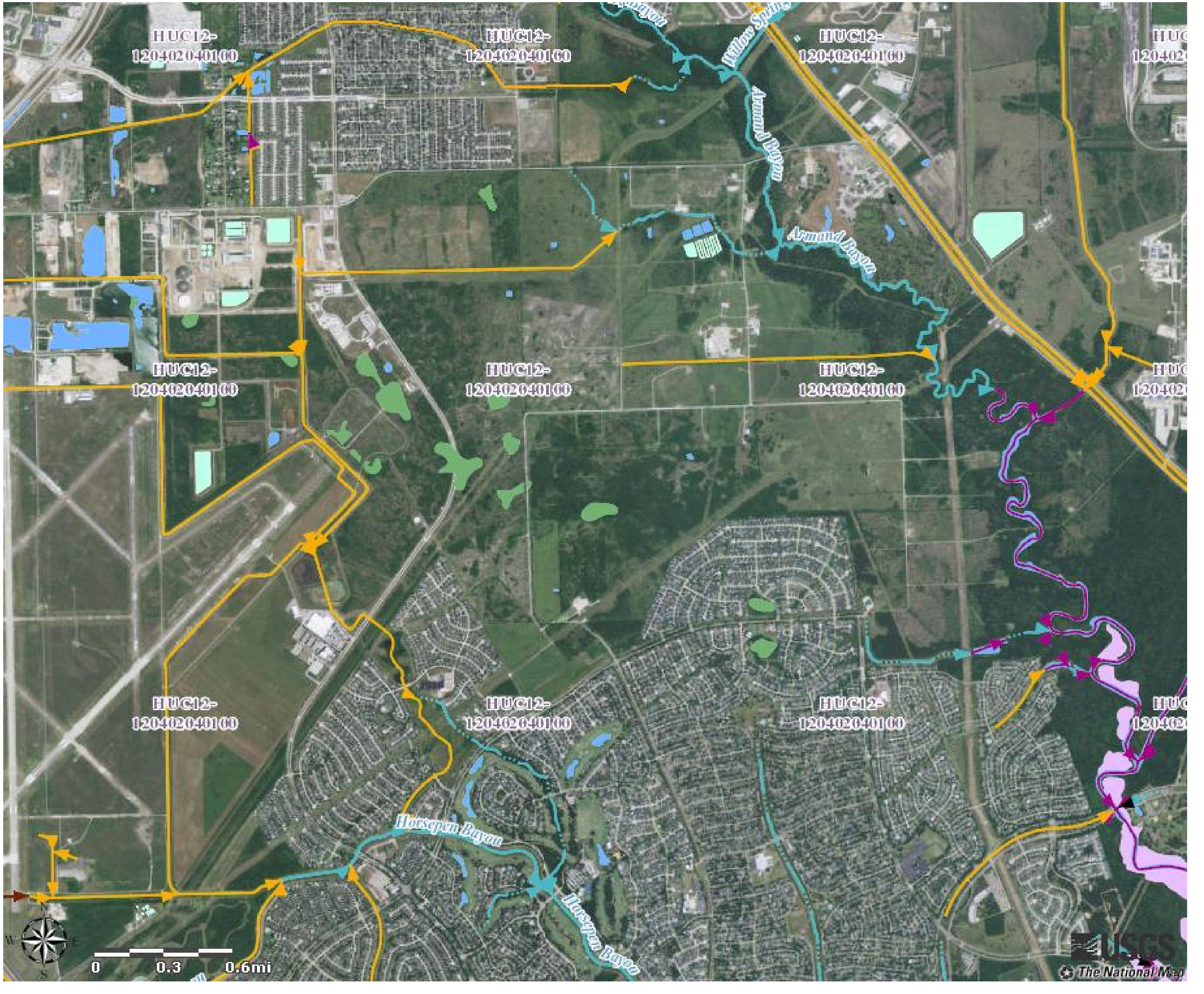
(1 : 62792.36)

HARRIS COUNTY FLOOD CONTROL DISTRICT

DISCLAIMER: The Harris County Flood Control District's Flood Education Mapping Tool is for general information purposes only and may not be suitable for legal, engineering or surveying purposes. The floodplains shown on this mapping tool are those delineated on the Federal Emergency Management Agency's (FEMA) effective Flood Insurance Rate Map (FIRM or floodplain map) for Harris County that was adopted in 2007, as well as updates that have been made through a Letter of Map Revision (LOMR) since 2007. This mapping tool is not an effective FIRM. The effective FIRM is produced, maintained and published by FEMA and not by the Harris County Flood Control District. Please visit FEMA's Map Service Center at www.msc.fema.gov to view the effective FIRM for Harris County. For an official floodplain determination, please contact an insurance agent or mortgage lender.This map is a representation and approximation of the relative location of geographic information, land marks and physical addresses.

Trendmaker

NOTES: Data available from U.S. Geological Survey, National Geospatial Program.



JD SWG-2013-00982

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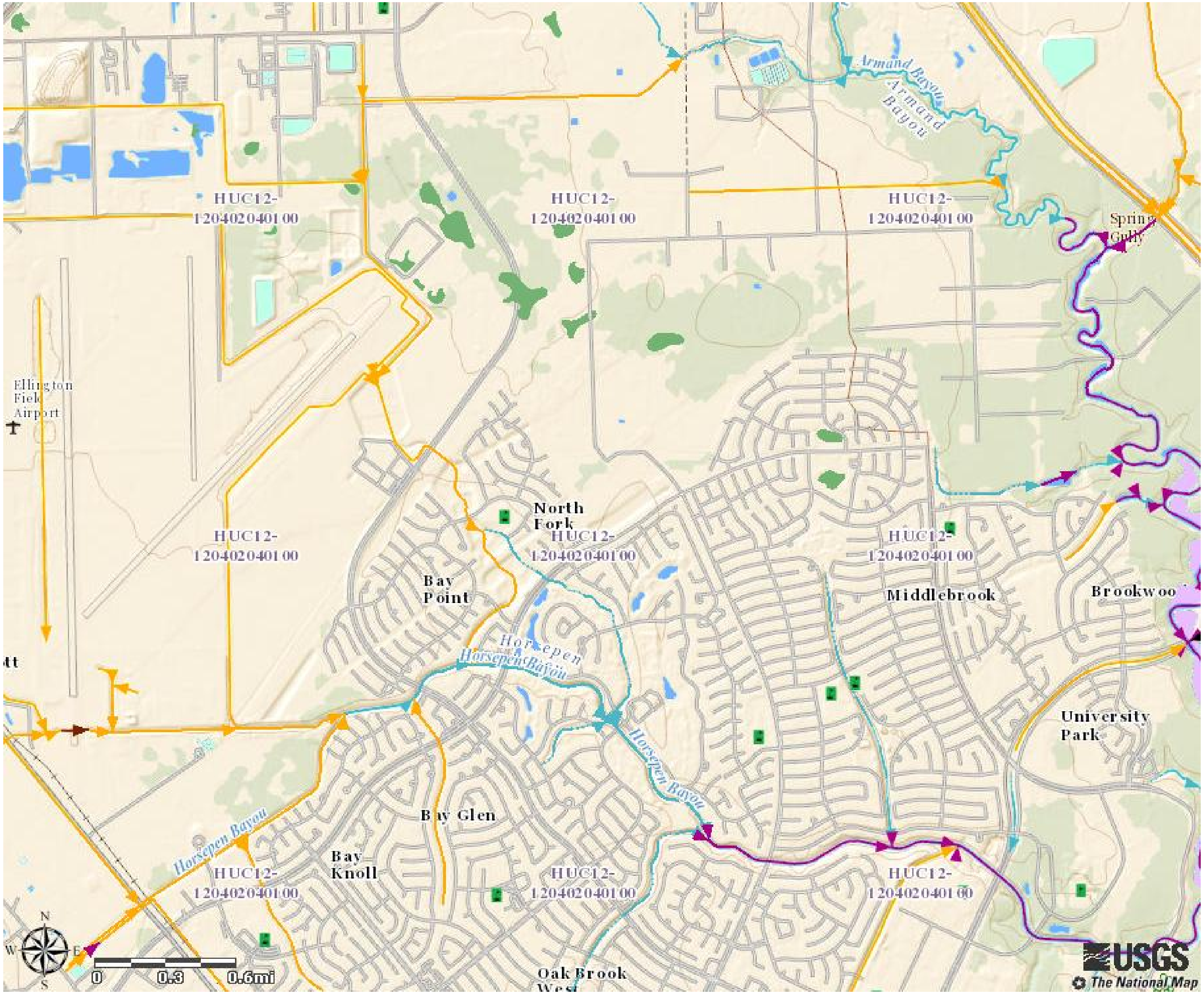
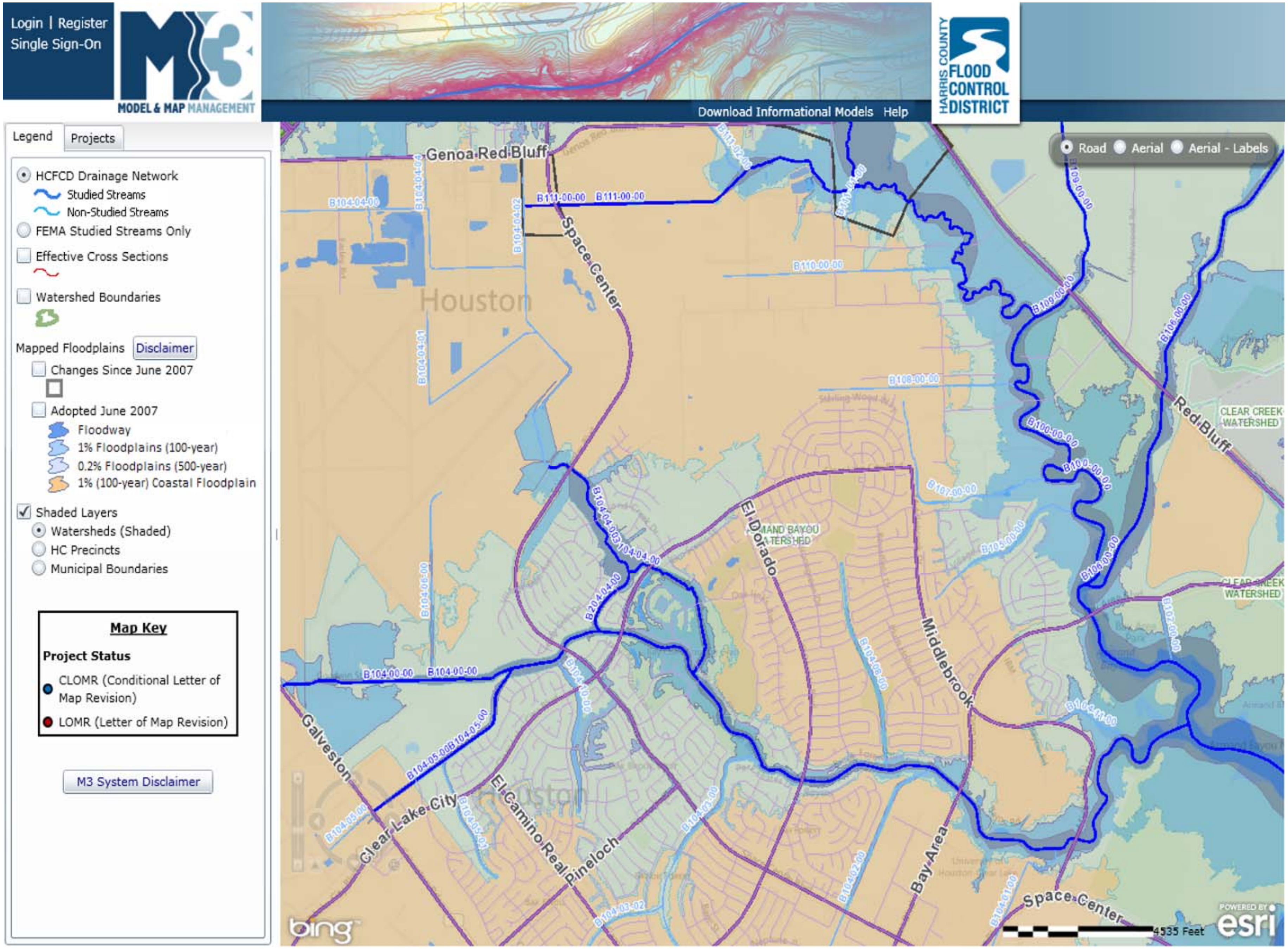


Open in The National Map Viewer

10/21/14 10:25 AM


Login | Register
Single Sign-On
M3
MODEL & MAP MANAGEMENT
Download Informational Models
Help
HARRIS COUNTY FLOOD CONTROL DISTRICT
Legend
Projects
HCFCD Drainage Network
Studied Streams
Non-Studied Streams
FEMA Studied Streams Only
Effective Cross Sections
Watershed Boundaries
Mapped Floodplains
Disclaimer
Changes Since June 2007
Adopted June 2007
Floodway
1% Floodplains (100-year)
0.2% Floodplains (500-year)
1% (100-year) Coastal Floodplain
Shaded Layers
Watersheds (Shaded)
HC Precincts
Municipal Boundaries
Map Key
Project Status
CLOMR (Conditional Letter of Map Revision)
LOMR (Letter of Map Revision)
M3 System Disclaimer
Road
Aerial
Aerial - Labels
Genoa Red Bluff
Space Center
Houston
Red Bluff
CLEAR CREEK WATERSHED
El Dorado
Middlebrook
Galveston
Clear Lake City
El Camino Real
Pineloch
Bay Area
Space Center
B111-00-00
B110-00-00
B109-00-00
B108-00-00
B107-00-00
B106-00-00
B105-00-00
B104-00-00
B104-04-00
4535 Feet
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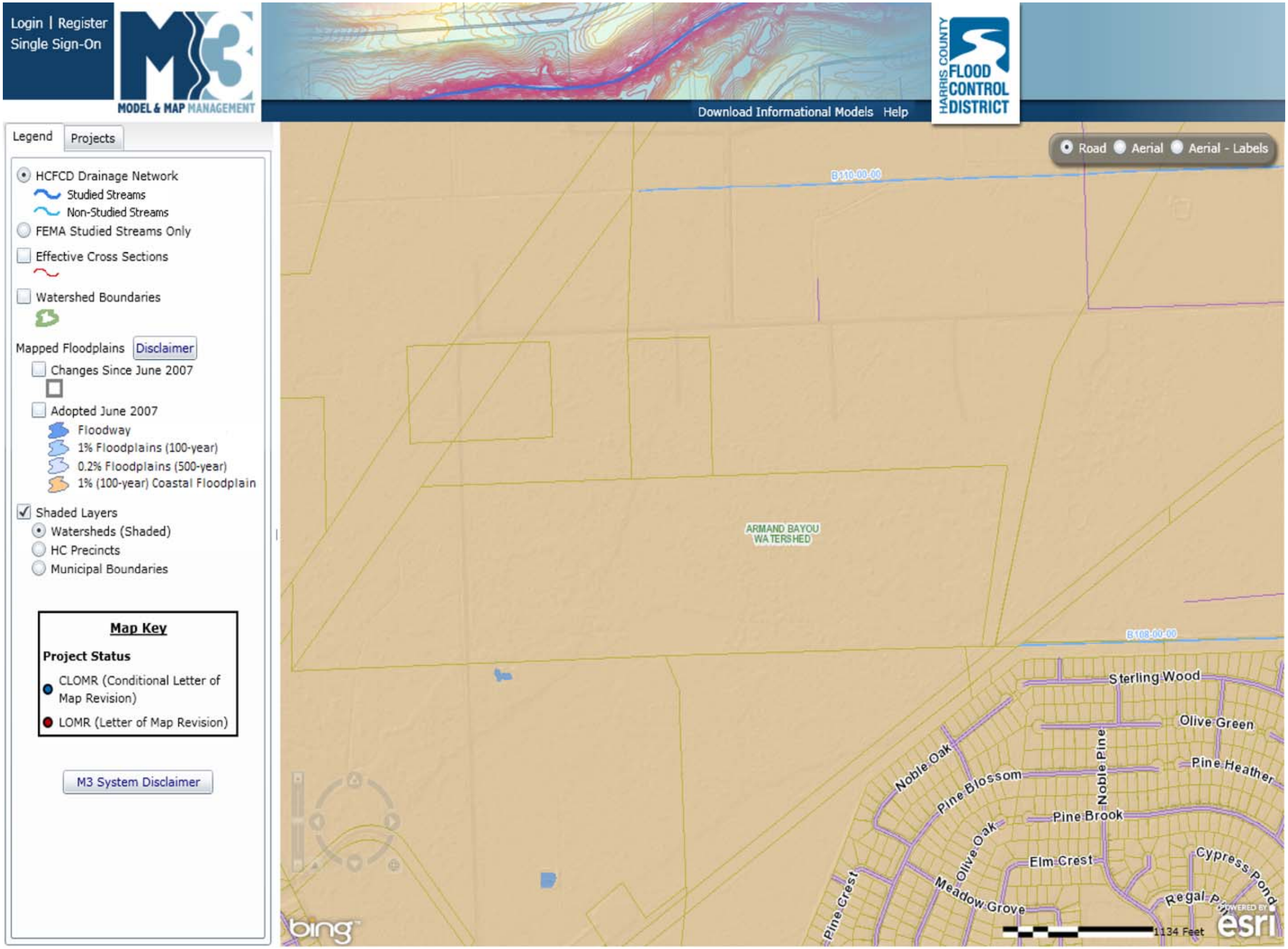
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MODEL & MAP MANAGEMENT
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HARRIS COUNTY FLOOD CONTROL DISTRICT
Legend
Projects
HCFCD Drainage Network
Studied Streams
Non-Studied Streams
FEMA Studied Streams Only
Effective Cross Sections
Watershed Boundaries
Mapped Floodplains
Disclaimer
Changes Since June 2007
Adopted June 2007
Floodway
1% Floodplains (100-year)
0.2% Floodplains (500-year)
1% (100-year) Coastal Floodplain
Shaded Layers
Watersheds (Shaded)
HC Precincts
Municipal Boundaries
Map Key
Project Status
CLOMR (Conditional Letter of Map Revision)
LOMR (Letter of Map Revision)
M3 System Disclaimer
Road
Aerial
Aerial - Labels
B110-00-00
ARMAND BAYOU WATERSHED
B108-00-00
Sterling Wood
Olive Green
Noble Oak
Noble Pine
Pine Heather
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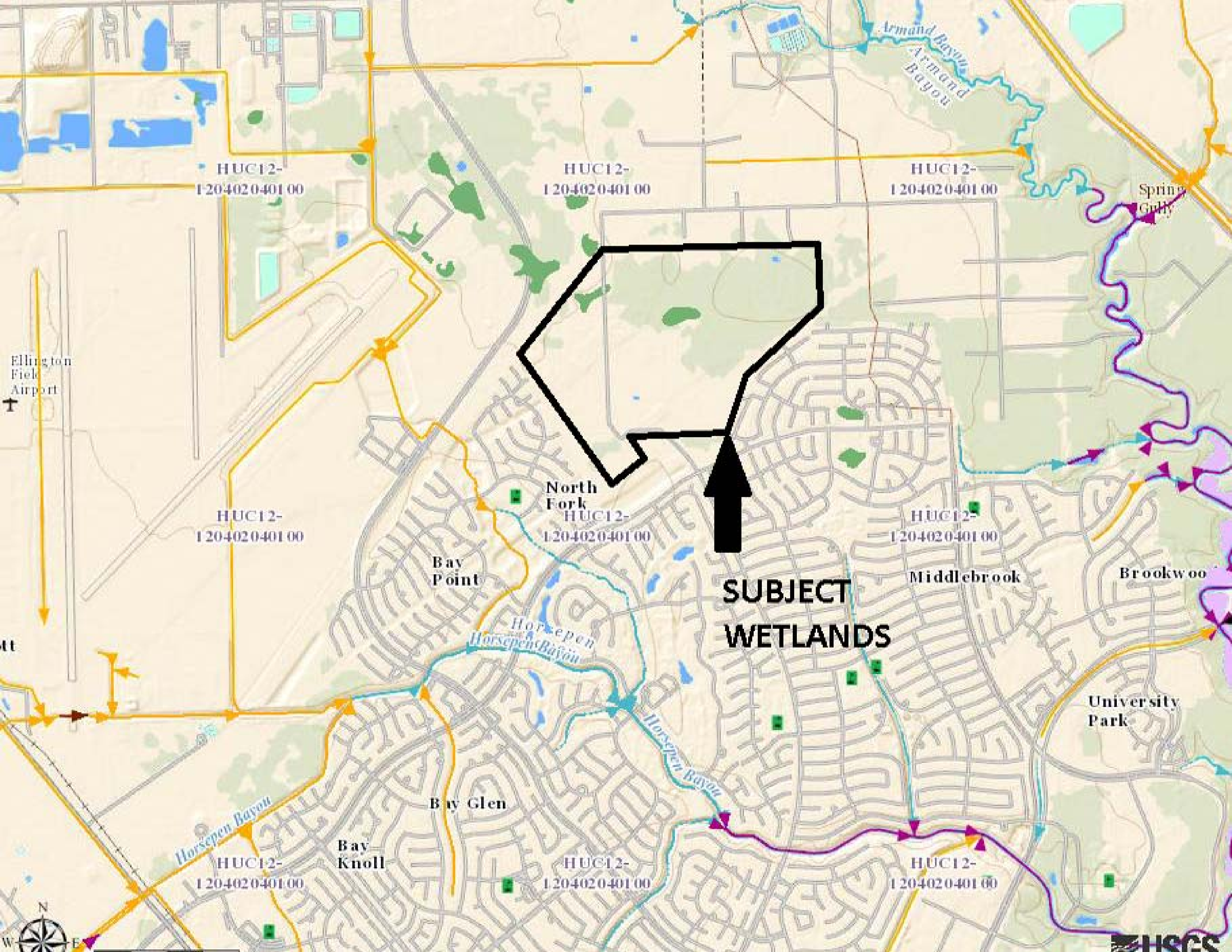

Armand Bayou
Armand Bayou
HUC12-120402040100
HUC12-120402040100
HUC12-120402040100
Spring Gully
Ellington Field Airport
North Fork
HUC12-120402040100
HUC12-120402040100
HUC12-120402040100
Bay Point
Middlebrook
Brookwood
SUBJECT WETLANDS
Horsepen Bayou
Horsepen Bayou
Horsepen Bayou
University Park
Bay Glen
Horsepen Bayou
Bay Knoll
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W
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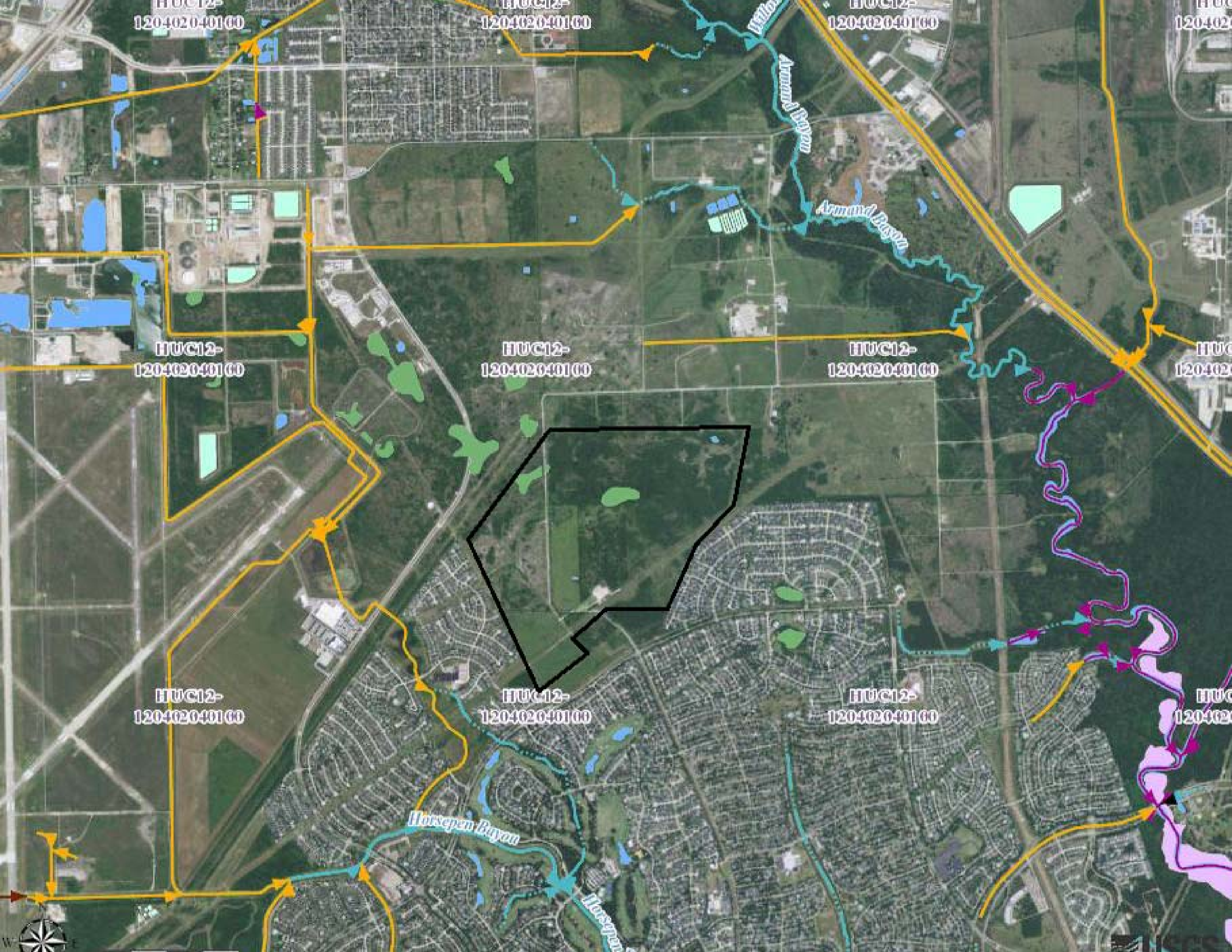

HUC12-
120402040100
Armand Bayou
Horsepen Bayou

Table of Contents

1. Introduction

1.1 Purpose and Scope

The purpose of this Master Drainage Plan of Existing Conditions report is to present the results of a detailed study of the existing drainage conditions of the City of League City, Texas.

The scope of services includes completing a graphical update of the previous master plan sheets utilizing ArcGIS. This software has made it possible for the Master Plan sheets to remain current with little effort. It will be possible to swap out aerials, overlay new LiDAR data or a new right-of-way line in order to ensure that the plan does not become outdated again. In this first phase, Dannenbaum has updated the exhibits through completion of the following tasks:

1. Collect Data needed to update exhibits; current hydrologic and hydraulic models, shapefiles, etc.
2. Update Aerials
3. Update Drainage Areas based on current Aerials, LiDAR, TSARP, League City Tributary Model updates completed for the Clear Creek Watershed Steering Committee, and other studies collected in Task 1
4. Show existing features
5. Utilize new FEMA floodplains for the areas with studied streams

The next phase of the scope of services includes identifying Master Plan opportunities, if possible. Since League City is mostly developed within the Clear Creek Watershed, master planning opportunities are limited. The Dickinson Bayou Watershed is not built-out yet; so many more master planning opportunities are possible. Improvements to Dickinson Bayou will be developer driven.

The previous master drainage plan prepared by LJA Engineering for the City of League City, 1990, was used as a basis for this master plan. The 1994 Dickinson Bayou master plan prepared by Dodson and Associates included mostly detention features. The primary objective of the study presented herein is to provide city officials with an inventory of existing drainage conditions. .

In addition to the Master Drainage Plan, other data and documents have been developed for the City. This includes a structural inventory within the 100-yr floodplain to determine areas with known flooding issues, and quantify those issues. The inventory of repetitive loss properties, ponding map and inventory of structures was utilized to help prioritize areas with flooding issues. The ponding map is shown behind the Ponding tab.

1.2 Use of Report

This report is designed to enable city officials, engineers and developers to readily identify existing drainage patterns within the City of League City.

1.3 Data Sources

Data utilized in the production of this report include LiDAR, aerial imagery, ArcGIS shapefiles, and previous reports and models. The source of the LiDAR, aerials, and models are noted in the Master Plan sheets.

1.3.1 LiDAR

For the Clear Creek watershed, the most up to date LiDAR was commissioned by the Houston Galveston Area Council (HGAC), was flown from February 2008 to March 2008 and is on the 2001 datum. The most up to date LiDAR for the Dickinson Bayou watershed was downloaded from the TNRIS website. The source of the LiDAR is indicated on each exhibit.

1.3.2 Aerial Imagery

Aerial Images that covered the entire City of League City were purchased from the HGAC. These images were flown from December 2007 to February 2008.

1.3.3 GIS Shapefiles

GIS shapefiles were collected from the City's GIS department, or created by Dannenbaum as part of the NPDES outfall collection program.

1.3.4 Previous Reports and Models

Previous models were collected from the libraries at the City and Dannenbaum. Dickinson Bayou models were collected from JKC's Dickinson Bayou Study completed for the Galveston County Consolidated Drainage District in December of 2008. Other consultants were contacted for models used for large planned communities.

The Clear Creek Master Plan completed in 1990, by LJA, and the Dickinson Bayou Master Plan dated 1994 by Dodson and Associates were also collected and considered for this master plan. The text for the 1990 League City Master Plan was the starting point for the text of this report.

2. Technical Evaluation

2.1 Overview

2.2 Hydrologic Concepts

Several fundamental concepts must be considered in the design of a comprehensive drainage system for a given area. Basic to these concepts is the determination of the amount of storm water runoff that will occur for design conditions. Urban drainage systems are designed for rainfall associated with a specific frequency of occurrence, referred to as a design storm. The rate of surface water runoff corresponding to the design storm must be estimated for the design of the drainage system. This estimate is determined by developing a relationship between the precipitation volume and intensity of the design storm and the drainage characteristics of the study area.

In order to predict the storm runoff resulting from a design rainfall, a fundamental understanding of the hydrologic budget of the region under study must be developed. A generalized hydrologic budget acts as an accounting system for water movement in an area. In general terms, precipitation in the form of rain, snow, hail, or sleet, develops from atmospheric water vapor and acts as the input to the hydrologic cycle. Some precipitation may be intercepted by trees grass and other vegetation and structural objects and will eventually return to the atmosphere by evaporation and transpiration. Once precipitation reaches the ground, some of it may fill depressions (referred to as depression storage), some may penetrate the ground (infiltrate) to become soil moisture or ground water, and the remainder will become surface runoff, which flows over the ground to a defined channel such as a creek, ditch or bayou.

The theoretical flow response of a drainage area to a given rainfall may be defined in terms of a storm hydrograph. By definition, a hydrograph is a continuous graph showing the amount of flow occurring with respect to time at a particular location. Each rainfall occurrence results in a particular runoff pattern and thus is associated with a characteristic storm hydrograph. The properties of rainfall intensity and duration combine with the physical characteristics of the drainage area, such as soil type, vegetative cover, depression storage, and the type of drainage system to form a characteristic runoff hydrograph which is unique to the storm pattern, season and drainage area. A hydrograph for an undeveloped area with no significant drainage system will have a lower peak and a longer time to peak than that of the same area if it were developed. The undeveloped area would have considerable ponding in the fields and along small roadside ditches. Construction of streets, buildings and drainage system improvements such as storm sewers and ditches within the area will result in a decrease in infiltration of rainfall to the soil, remove the natural depression storage and provide a more efficient storm water drainage system. Control of the impact of development is the primary objective for the Mater Drainage Plan for League City. Development of the rural areas within the City can increase flood flow rates. The proposed channels and detention basins discussed in this report have been planned to control the increased discharge that may result from development.

2.3 Hydraulic Concepts

In addition to the fundamental hydrologic concepts mentioned above, an understanding of hydraulics is also essential for development of an efficient drainage system design. Basically, the overland flow occurring during a storm event becomes shallow concentrated flow and is carried into the gutters, streets, storm sewers, ditches or natural streams which comprise the channelized drainage system of the area. An urban drainage system consists of four distinct elements:

1) Major receiving streams or bodies of water in their natural existing condition.
2) The primary channels which include improved natural streams, bayous and creeks.
3) The lateral outfall channels which are tributaries of the primary channels.
4) The secondary system of storm sewers, small ditches and roadside ditches in developed areas.

The major receiving streams serve to transmit the surface runoff downstream to a major river, lake or ocean. The water surface elevation in these channels should ideally allow for full conveyance of flows from improved primary channels and lateral channels. In some situations, detention is needed because primary channels and laterals do not have enough conveyance, and it is not cost effective to add conveyance. . No downstream impact is required. In the League City area, the major receiving streams include the tide-affected reaches of Clear Creek and Dickinson Bayou, both of which ultimately drain into Galveston Bay.

The primary channels serve to collect storm runoff from each area served by the drainage system. In addition, the primary channels of a drainage system must be able to convey water efficiently from the lateral channels and secondary system to the major receiving streams. The primary channels draining to Clear Creek or Clear Lake include Magnolia Creek, Newport/Landing Ditch, Corum Ditch, Interurban Ditch, Robinson Bayou, and Jarbo Bayou. West Dickinson Bayou, Dickinson Bayou By-Pass Channel, Cedar Creek, Bordens Gulley, Magnolia Bayou, Benson Bayou and Gum Bayou outfall into the tide-affected portion of Dickinson Bayou. The primary channels and the drainage areas are shown on Exhibit 1.

The lateral outfall channels are tributaries designed to convey storm sewer drainage and roadside ditch drainage to the primary drainage system.

The secondary system functions as the collector of overland runoff. This system may be nonexistent in undeveloped areas or may be in the form of minor swales or rural roadside ditches. In urban areas, gutters of city streets, the streets themselves, storm sewers, roadside ditches, and small improved channels function as the secondary drainage system and serve to collect and convey runoff to the lateral outfall channels.

2.4 Analysis of Drainage Basins

In order to predict the peak flow to be used in the design of a drainage system for a given area, the physical characteristics of the area must be defined and analyzed. The volume of runoff represented by a hydrograph is dependent on rainfall volume and rate, antecedent rainfall, depression storage, interception, infiltration, evaporation, and the contributing drainage area size. The effect of each of these factors is dependent on basin characteristics, hydrologic conditions, and soil type.

Initially, the areas within the City of League City and its extraterritorial jurisdiction, as well as adjoining areas which influence drainage conditions in League City, were taken from the previous master plan (1990). The areas were then refined based on new LiDAR, new subdivision development, and the layout of the storm sewer system. After the drainage areas were delineated, basin characteristics were measured. Two different methodologies were used to model the basins in League City; TSARP and Pre-TSARP. In both methodologies, for each drainage basin or sub-basin, computations were performed to determine the total area and the percentage of the basin which is currently developed. An estimate of the percentage of impervious cover (i.e. buildings, parking lots, roads, etc.) in each basin was also determined.

Pre-TSARP methodology included:

- An infiltrations loss method of Initial and Constant.
- Onsite detention was not taken in to account for the Tc & R calculations.
- The rainfall peak that was used was 12 hours, and the rainfall data was TP-40 plus 2%.
- Contraction and expansion coefficients of 0.1 and 0.3 respectively were used at all locations were applicable.
- Manning's N values of 0.07 for overbanks and 0.045 for channels were used on all streams.
- These streams were also junctioned together in one model, so the tailwater conditions were set by the model except for at the mouth of Dickinson Bayous, which was normal depth.

TSARP methodology included:

- An infiltrations loss method of Green and Ampt method compatible with previous analysis by HCFCD.
- Onsite detention was considered in the Tc & R calculations.
- A rainfall peak of 16 hours was used as well as the rainfall that was developed by HCFCD as part of TSARP.
- Contraction and expansion coefficients of 0.3 and 0.5 respectively
- Manning's n-values varied based on field observations and aerial images.
- The streams were modeled separately, and the downstream boundary condition was set to normal depth.

The following table shows which model was used for each of the profile sheets included.

Stream Name	Methodology	Company	Date
Clear Creek	TSARP	DEC	2006
Magnolia Creek	TSARP	DEC	2006
Corum Ditch	TSARP	AECOM	2009
Interurban Ditch	TSARP	DEC	2006
Landing Ditch	TSARP	DEC	2006
Robinson Bayou	TSARP	DEC	2006
Jarbo Bayou	TSARP	DEC	2006
Dickinson Bayou	Pre-TSARP	JKC	2008
Magnolia Bayou	Pre-TSARP	JKC	2008
Borden's Gully	Pre-TSARP	JKC	2008
Benson Bayou	Pre-TSARP	JKC	2008
Gum Bayou	TSARP	DEC	2009

2.5 Evaluation of Channel System

Existing lateral outfall channels and primary channel systems has to be defined before the planning of drainage improvements could be implemented. Each drainage basin designed for the League City area was evaluated in detail with respect to the number, type, size and pattern of drainage channels. Drainage systems in each basin ranged from virtually nonexistent in the more remote rural areas, to well-defined channels in developed urban areas within League City.

For each of the studied lateral drainage systems, characteristic physical parameters were defined for use in developing the existing runoff hydrograph for each drainage basin. Channel lengths and average slopes were calculated using LiDAR. Representative roughness coefficients were determined from the aerial photographs, previous hydrologic studies performed in the area and field observation. Channel geometry was developed using LiDAR and field survey.

3. Design Considerations and Requirements

3.1 Overview

Based on the general hydrologic and hydraulic concepts described in Section 2, design criteria were developed specifically for the City of League City in conjunction with the Master Drainage Plan and are presented in this section. Additionally, the current design criteria being used in the City of League City according to the 1990 Master Plan, and the City's Subdivision Ordinance, as well as current criteria for Galveston County, the City of Houston, Harris County, and other surrounding areas was reviewed. Specific design criteria defined in the following paragraphs include the appropriate rainfall frequency and discharge methodology selected for use in the study area, as well as specific hydrologic and hydraulic criteria used for the planning of storm sewers, channel improvements and detention facilities in the Master Drainage Plan.

Briefly, the design criteria currently in use by most governmental entities in the vicinity of the City of League City follows the Harris County Flood Control District's (HCFCD) Policy Criteria & Procedure Manual (PCPM). The HCFCD design criteria manual specifies that all open channels will be designed to contain the runoff from the 1% exceedance probability storm event. Together with the curb-and-gutter system, site grading, and roadside ditches, the secondary system is designed to hold and convey the 100-year frequency storm runoff to the lateral outfall channel without structural flooding.

3.2 Rainfall Frequency Analysis

3.2.1 Dickinson Bayou Watershed

The U.S. Weather Bureau Technical Paper No. 40 (TP-40) is the most widely used reference for storm frequency data in Galveston County. Published in 1967, TP-40 analyzed historical rainfall data and developed rainfall frequency curves across the United States. From the historical data, a rainfall intensity (inches per hour) versus duration curve particular to each local area was developed. The 100-year, 24-hour rainfall produced by TP-40 for the Houston area is 12.7 inches, which varies in intensity to reflect 100-year volumes for smaller durations. For the Galveston area, the 100-year, 24-hour rainfall predicted by TP-40 is 13.4 inches. A mean value for the 100-year, 24-hour rainfall for the City of League City is 13.0 inches as interpolated between the values for the City of Houston and the City of Galveston. Based on this, the rainfall values used in TP-40 should be increased by two percent for use in the Dickinson Bayou part of League City.

3.2.2 Clear Creek Watershed

As part of the Tropical Storm Allison Recovery Project (TSARP), the rainfall frequency and duration curves were updated and put into a table. The 100-year, 24 hour rainfall produced by these updated tables is 13.5 inches for the Clear Creek watershed. The tables were developed from rainfall obtained from the United States Geological Service (USGS). The HCFCD Hydrologic and Hydraulic Guidance Manual includes rainfall data for different frequencies and durations and should be used for the Clear Creek watershed part of League City.

3.3 Hydrologic Analysis

Hydrologic methodology used by the Harris County Flood Control District and the City of Houston was used in development of the master drainage plan. The same methodology is required for use in future hydrologic analysis and design in the City of League City,

3.3.1 Storm Sewers

The storm sewer should be designed to convey the 2-year frequency flow based on the City of Houston design curves which were derived from the rational formula, Q = CIA, where

Q = discharge in cubic feet per second,

C = runoff coefficient,

I = rainfall intensity, in inches per hour, and

A = drainage area, in acres.

The rational method is applicable to areas less than 600 acres for storm sewer, and less than 500 acres for roadside ditches. For areas larger than that, the Clark Unit Hydrograph Tc & R should be used. The City of League City C values, taken from the City of Houston, are summarized as follows:

Land Use Type	Run-off Coefficient (C)
Residential District	
Lots more than ½ acre	0.35
Lots ¼ - ½ acre	0.45
Lots less than ¼ acre	0.55
Multi-Family areas	
Less than 20 Service Units/Acre	0.65
20 Service Units/Acre or Greater	0.80
Business Districts	0.8
Industrial Districts	
Light Areas	0.65
Heavy Areas	0.75
Railroad Yards Areas	0.3
Parks/Open Areas	0.18

3.3.2 Drainage Channels

The HCFCD methodology for determining channel design flows and hydrographs is described in detail in the previously referenced HCFCD Policy, Criteria and Procedures Manual, published by HCFCD in 2004. This method uses the coefficients Tc (representing time of concentration) and R (representing a storage factor), calculated from the drainage basin physical parameters, to develop an U.S. Army Corp of Engineers' HEC-HMS computer model. The HEC-HMS model produces a storm hydrograph by using precipitation data, basin areas, percent imperviousness, rainfall loss rates and channel characteristics to develop a specific runoff pattern for the particular storm and drainage area. HCFCD hydrologic methodology and comprehensive documentation are the required methodology for use in the City of League City in the areas where detailed development of a runoff hydrograph is required for design.

3.3.3 Detention Basins

For planning and design of detention basins the methods presented in the HCFCD design criteria manual are required for use in League City.

3.4 Hydraulic Design Requirements

3.4.1 Storm Sewers and Roadside Ditches

3.4.1.1 Tailwater

It is required that storm sewers be designed based on City of Houston tailwater criteria. The starting tailwater will be different based on two factors, distance from receiving stream and storm frequency. For storm sewers that outfall less than 2,000 ft from the receiving stream, the criteria will be as follows:

1. For the 2-yr design rainfall event with non-submerged outfall to the receiving channel, the starting tailwater shall be top of pipe.
2. For the extreme rainfall event and outfall to the receiving channel, the starting tailwater shall be the 10-yr WSEL or 24-in below top of bank, whichever is lower depending on the level of service of the receiving channel.

If the receiving channel for the storm system being analyzed is greater than 2,000 ft from the project limits, then the starting tailwater may be determined from an outfall point, or truncation, downstream of the project interconnect point, as noted below:

1. For the 2-yr design rainfall event the starting HGL shall be the top of pipe 2,000 ft downstream of the project interconnect point assuming pipes are connected at soffit. If pipes are connected at flow line, the top of the larger receiving pipe must be used. If a starting tailwater other than the top of pipe is chosen, the consultant shall analyze the storm system from outfall at the receiving channel upstream to the point of interconnect to demonstrate the alternate starting HGL value. Low resolution dynamic modeling or simple trunkline analyses using WinStorm are reasonable methods.
2. For the extreme rainfall event the starting HGL shall be 24 in above the top of pipe 2,000 ft downstream of the project interconnect point. If a starting tailwater other than 24 in above the top of pipe is chosen, the consultant shall analyze the storm system outfall at the receiving channel upstream to the point of interconnect to demonstrate the alternate starting HGL value. Low resolution dynamic modeling or simple trunkline analysis using WinStorm are reasonable methods. Static tailwater allowed.

For the hydraulic impact analysis, a variable tailwater at the downstream end of the model may be used.

3.4.1.2 Ponding and Roadway Elevation

All of the following criteria must be considered for ponding:

- The design frequency for consideration of overland sheet flow will consider the 1% events. These events, which exceed the capacity of the underground storm sewer system and result in ponding and overland sheet flow, shall be routed to drain along street rights-of-way or open areas and through the development to a primary outlet.
- Streets shall be designed so that consecutive high points in the street will provide for a gravity flow of drainage to the ultimate outlet.
- The maximum depth of ponding at high points shall be 6 inches above the gutter line during a 1 % event. .
- The maximum depth of ponding at low points shall be 18 inches above the gutter line during a 1 % event.
- Along major thoroughfares and principal arterial streets, the inside lane should be dry during the 1% event. .
- The maximum depth of ponding elevation for the 100-year event at any point along the street shall not be higher than the natural ground elevation at the right-of-way line.

Setting Roadway Elevations:

- New thoroughfares should have a minimum low point (gutter line) that is at or above the base flood elevation.

3.4.2 Drainage Channels

Hydraulic design of drainage ditches should be based on HCFCD criteria. Per HCFCD criteria, the 100-year flood should be contained within the right-of-way.

Starting water surface elevation for backwater computations using HEC-RAS should also be based on HCFCD criteria. Starting water surface elevation at the mouths of open channels should be based on the normal depth in the design channel calculated using Manning's equation, or the normal depth function in HEC-RAS. However, starting water surface elevations for streams entering tidal zones should use average high tide as a starting water surface.

Side slopes in the HCFCD criteria manual for unlined earthen or grass-lined channels are no steeper than 4 horizontal to 1 vertical with a 20 ft maintenance berm for channels with a top width of less than 60 ft and less than 7 ft deep or

30 ft maintenance berm for larger channels. In the League City area, side slopes for unlined earthen or grass-lined channels should be no steeper than 4 horizontal to 1 vertical to provide easier maintenance.

A soils report is required to verify the angle of repose and shall be provided to the City of League City.

3.4.3 Detention Basins

The HCFCD criteria manual presents a detailed methodology for hydraulic analysis and design criteria for detention basins which is required for use in the City of League City. One modification to HCFCD criteria is that outfall structures subject to tailwater inundation may have flap gates to prevent back flow.

3.4.4 Drainage Structures

Drainage structures consist of drop structures (energy dissipaters), culverts, bridges, storm sewer outfalls, and detention basin control structures. Detention basin control structures are covered in the detention section. It is required that these structures be design based on HCFCD criteria.

3.4.5 Right-of-Way Requirements

Right-of-way requirements should be based on HCFCD criteria as shown in the Table below.

Channels That Are	The Minimum Berm Width Is
Grass-lined with a top width > 60 feet or a depth of > 7ft	30 feet
Grass-lined with a top width <= 60 feet or a depth of <= 7ft	20 feet
Grass-lined where side slopes are 8 (horizontal): 1 (vertical) or flatter	10 feet
Grass-lined with the 20-foot maintenance access on a bench	10 feet
Lined with riprap or articulated concrete blocks or partially concrete-lined	Same as grass-lined channel
Fully concrete-lined	20 feet one side, 10 feet other side

3.5 Master Drainage Plan

The Master Drainage Plan for the City of League City is presented in plan and profile at a scale of 1 inch = 1,000 feet. The plan exhibits and profiles are presented by drainage basins. Exhibit 1 identifies the individual basins within the city. In addition to the individual basins, there are several intervening areas which drain directly to either Clear Creek or Dickinson Bayou. Exhibit 2 presents an index of exhibits. The watersheds in Clear Creek are in Exhibits 3 through 7 under the MDP tab. The watersheds for Dickinson Bayou are in Exhibits 8 though 11 under the MDP tab. The plan views for a particular basin are presented first followed by the existing channel profiles for that basin. In the next phase of this project, proposed features will be modeled, and the profiles for these models will be updated to include proposed profiles. Any proposed features would be intended to alleviate existing problems, not to mitigate for future development. Any future development would be required to provide mitigation for any impacts introduced by the development. Specific details of existing conditions of each watershed are in the following text.

3.6 Clear Creek

Exhibits 3 through 7 under the MDP tab present the existing conditions for the areas of League City which drain into Clear Creek and Clear Lake. Since the previous master plan was completed in 1990, this watershed has developed significantly and is mostly developed. There is little undeveloped area remaining that would require new features. It has been assumed that runoff for areas upstream of League City will be controlled by the appropriate jurisdiction to prevent any increase in peak flood flows along Clear Creek through League City.

The following is a specific discussion of the basins which drain to Clear Creek.

3.6.1 Magnolia Creek

Magnolia Creek drains approximately 3,492 acres in northwest League City. The most recent model for this area was completed by DEC in 2006 and was completed using TSARP methodology. The eastern portion of the watershed is fully developed, however an undeveloped section remains in the western portion of the watershed.

Since no stream currently exists in the undeveloped part, future development should consider the possibility of extending Magnolia Creek to the west to provide an outfall ditch. The proposed extension will require modeling to determine if the decrease in time of concentration due to the proposed channel causes impacts, and therefore requires detention. It is assumed that any development would provide detention to mitigate for the increase in impervious cover. As seen in Exhibit 3E, the current channel has capacity, so no improvements are needed on the existing channel.

3.6.2 Newport – Landing Ditch Basin

Landing Ditch is the main drainage system of the total Newport-Landing Ditch basin. Since Landing Ditch outfalls to Clear Creek near the mouth of Newport Ditch, these two systems can generally be considered as separate basins. The drainage area for Landing Ditch is 1,734 acres, as shown on Exhibit 5. This basin is mostly developed, except for the south eastern corner. Newport Ditch drains about 340 acres above the mouth of Landing Ditch and is shown in Exhibit 5.

The most up to date model was completed in 2006 by DEC. As seen in the profile on Exhibit 5D under the MDP tab, the 1% Chance Flood WSEL is in the banks.

3.6.3 Corum Ditch

Corum Ditch, as shown on Exhibit 5 under the MDP tab, drains 402 acres. The channel begins west of Interstate Highway 45 (IH-45), as an IH-45 feeder ditch, and drains through the Corum Ditch Shopping Center, then under FM 518 to Clear Creek. The most up to date model was completed in 2009 by AECOM. As seen in Exhibit 5E under the MDP tab, the 1% Chance Flood WSEL is in the banks with the exception of the portion downstream of the crossing at Wesley.

3.6.4 Interurban Ditch

Interurban Ditch is partially located within the Centerpoint Energy easement. Interurban Ditch drains 914 acres. The ditch is adjacent to and under the east power line towers. This basin is mostly developed, and channels have been built to serve the areas that have not been fully developed.

There is street flooding in the Oaks of Clear Creek subdivision due to the lack of elevation drop between the subdivision and the mouth of Interurban Ditch. This subdivision is located at the upstream end of the Interurban Ditch, where the ditch is in a box. This area has been studied and improvements have been proposed as part of a separate report entitled Evaluation of Drainage Improvements for Oaks of Clear Creek Sections 1 and 2, by Dannenbaum Engineering, dated August 2010. There are no further improvements proposed.

3.6.5 Robinsons Bayou

Robinsons Bayou is shown on Exhibit 6. Robinsons Bayou drains 3,236 acres. Since the previous master plan, much of the previously undeveloped area has been developed.

As seen on Exhibit 6E under the MDP tab, the 1% Chance Flood WSEL is within the banks. The current model shows the channel to have sufficient capacity. Upstream drainage improvements may be necessary to serve future development.

3.6.6 Jarbo Bayou

Jarbo Bayou drains 3,420 acres and is shown on Exhibit 7. This basin is almost fully developed with channels built to serve the areas that are not yet fully developed.

As seen in Exhibit 7E, the 1% Chance Flood WSEL is within the channel banks based on the model completed in 2006 by DEC.

3.7 Dickinson Bayou

Exhibits 8 through 11 present the drainage plan for the area draining to Dickinson Bayou. Dickinson Bayou and its tributaries through the Village of Dickinson have limited capacity[1]. Environmental concerns, existing structures and permitting problems generally prohibit improvement of these channels. Due to these factors, most development within the Dickinson Bayou Basin will require stormwater detention basins. The following is a specific discussion of the Dickinson Bayou system.

3.7.1 West Dickinson Bayou Basin

The West Dickinson Bayou designation applies to the portion of the Dickinson Bayou Basin west of Cedar Creek.. The West Dickinson Bayou drainage area is approximately 16 square miles, of which 2.6 square miles (1,646 acres) are within the City of League City. The main drainage feature of the West Dickinson Bayou Basin is the By-Pass Channel. The channel originates just east of Alvin and crosses Dickinson Bayou once before entering Dickinson Bayou through Cedar Creek. An existing diversion structure allows a portion of the flow to be diverted to Dickinson Bayou which flows south under FM 517 and then flows east towards the Village of Dickinson. The remainder of the By-Pass Channel flow and flow from adjacent areas enter Cedar Creek upstream of FM 517. Cedar Creek drains south under FM 517 to Dickinson Bayou

3.7.2 Prairie Estates Ditch Area

The 560-acre area east of Cedar Creek, as shown on Exhibit 8E under the MDP tab, drains south into two small channels. The western channel has been master planned to drain the area north of FM 517. One 20 acre detention basin was proposed to serve the area in the previous Master Plan. This basin and channel should be investigated for future development to determine its effectiveness.

3.7.3 Magnolia Bayou – Bordens Gully Drainage Basins

Magnolia Bayou and Bordens Gully drain approximately 4,988 acres. Both stream flow easterly under IH-45 through the Village of Dickinson to Dickinson Bayou.

The areas east and immediately west of IH-45 have been developed. Detention storage will be required for the remainder of the Magnolia Bayou and Bordens Gully basins. The master plan completed in 1990 includes the construction of a diversion channel from north of Magnolia Bayou, across Bordens Gully and south to Dickinson Bayou, but much of this area has been developed making the complete diversion channel no longer feasible. Portions of diversion channel

[1] League City Master Plan, LJA, 1990

could be built; further analysis would be required to see if this feature still provides benefits.

3.7.4 Benson Bayou Drainage Basin

Benson Bayou drains a 3,107 acre area between IH-45 and Dickinson Avenue, with 2,103 acres within the City of League City. Exhibit 10 presents the existing conditions for Benson Bayou. This basin is mostly developed; however, the detention pond area proposed in the master plan completed in 1990 has not been developed and may still be available for detention. This detention will require investigation when future development occurs.

3.7.5 Gum Bayou

Gum Bayou, and its main tributary, West Gum Bayou, drain approximately 7,533 acres, of which 3,200 acres are within the City of League City. Exhibit 11 shows Gum Bayou basin. Since the previous master plan (1990), most of the basin has been developed, so the proposed features can no longer be built. There are no new proposed features for this basin. Future development will determine the addition of drainage features in this area.

4. Ponding Map

A ponding analysis, based on the most current LiDAR, was performed within the City of League City boundary. This analysis was performed to give the City general knowledge of where ponding of water is located during rainfall events.

For the purpose of this analysis, DEC considered a pond as any cell(s) in the DEM surrounded by cells with a higher elevation in which water is trapped and is unable to flow out freely. In order to create a DEM that does not contain any ponding areas, the "Fill Sinks" function of ArcHydro, an extension of ArcGIS, was utilized. The resulting DEM was then subtracted from the original DEM through the "Raster Calculator" function within the Spatial Analyst extension of ArcGIS. This process produced a DEM of areas where ponding exists within the city limits. The ponding areas were classified based on depth and can be viewed under the Ponding tab.

5. Future Development

All proposed features shall be modeled using current conditions. The City of League City has had significant development since the previous master plan and the modeling methods have been updated, so it is crucial that the proposed features be reevaluated.

Drainage reports must include a no adverse impact statement. The City of League City requires that developments create no rise or have no adverse impact on receiving streams.

Improving Water Quality in the Armand Bayou Watershed

A TMDL Project to Restore Recreational Uses

Armand Bayou is a coastal stream located in the San Jacinto–Brazos Coastal Basin. High concentrations of bacteria, which are found in both human and animal waste, have been observed in the bayou. The presence of these bacteria may indicate a health risk to people who swim or wade in the bayou—activities referred to as contact recreation.

In response to this condition, the TCEQ initiated a *total maximum daily load* (TMDL) project to determine the measures necessary to improve water quality in the bayou.

A TMDL is like a budget for pollution—it determines the amount (or load) of a pollutant that a body of water can receive and still be suitable for all its uses. The allowable load is then allocated among categories of sources within the watershed. Stakeholders work with the state to develop a plan to implement TMDLs (I-Plan) with measures that reduce pollution.

Learn more about water quality standards and management by reading *Preserving and Improving Water Quality*, available on our website at <www.tceq.texas.gov/waterquality/tmdl/>.

Armand Bayou Watershed

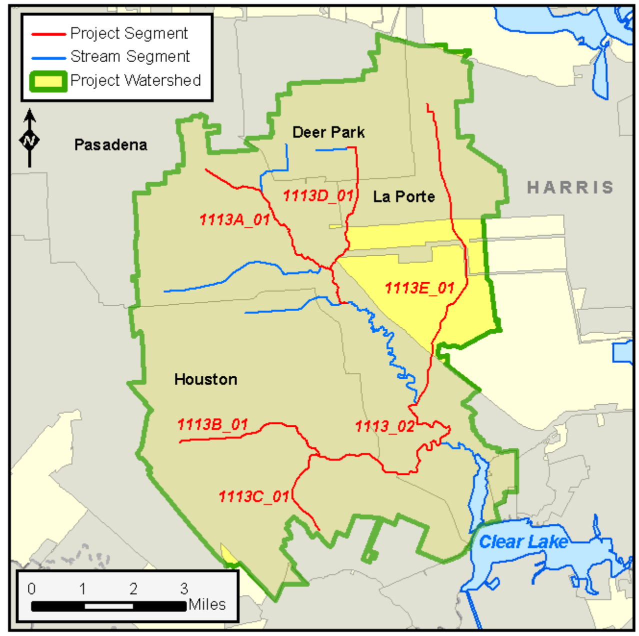
Armand Bayou originates south of Houston and flows southeast through the city of Pasadena into Clear Lake. The lower eight miles of the bayou are tidally influenced. However, the watershed for the portion of Armand Bayou above tidal influence is highly urbanized, with extensive residential development.

The watershed of Armand Bayou extends 59.1 square miles and includes portions of Harris County and the cities of Houston, Pasadena, Deer Park, and La Porte.

The segments included in the TMDL project are:

- 1113 - Armand Bayou Tidal, AU 1113_02
- 1113A - Armand Bayou Above Tidal, AU 1113A_01
- 1113B - Horsepen Bayou Tidal, AU 1113B_01
- 1113C - Unnamed Tributary to Horsepen Bayou, AU 1113C_01
- 1113D - Willow Springs Bayou, AU 1113D_01
- 1113E - Big Island Slough, AU 1113E_01

Armand Bayou is an important community resource, rich in plant and animal life, that attracts canoeists, kayakers, fishermen, and birdwatchers daily. There



are several parks and other recreational areas along Armand Bayou, including Bay Area Park and Armand Bayou Nature Center.

The Nature Center protects remnants of the region's original wetland, bottomland forest, and tall grass prairie ecosystems. This area has been designated as one of only four Texas State Coastal Preserves and is one of the last bayous in the Houston area that is not channelized in the tidal reaches.

Project Development

Regional stakeholders, represented by the Armand Bayou Watershed Partnership, have been very active in preserving Armand Bayou, and worked closely with the TMDL Team on a survey of aquatic life uses of the bayou that was completed in 2003.

In 2011, the TMDL Team completed a survey of recreational uses and submitted it to the TCEQ's Standards Work Group for analysis. The TCEQ also presented the survey results to stakeholders at a public meeting, where stakeholders expressed a preference for preserving the current recreational use standard.

Based on stakeholder preferences and results from the survey, the TMDL Team secured funding and began work on developing bacteria TMDLs for the bayou with the help of a specialist at the University of Houston.

Public Participation

In all its projects, the TCEQ seeks to gather opinion and information from people who represent government, permitted facilities, agriculture, business, environmental, and community and private interests in the watershed. The TCEQ solicits advice and comment from these stakeholders at meetings and through print and electronic media notices.

The Houston–Galveston Area Council (H-GAC) is coordinating public participation in this project. A Coordination Committee was developed to make decisions regarding implementation of the TMDLs. The Committee chose to petition the Bacteria Implementation Group (BIG) to join its I-Plan, which was approved by the TCEQ in January 2013. It addresses bacteria impairments in many water bodies in the greater Houston area, and covers an area directly adjacent to the Armand Bayou watershed. The BIG voted to accept this petition in May 2014.

For More Information

Contact one of the people listed, or visit the project website at:

<www.tceq.texas.gov/waterquality/tmdl/89-armandbacteria.html>

TCEQ Central Office:
Jason Leifester, TMDL Project Manager
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512-239-3604, lauren.oertel@tceq.texas.gov

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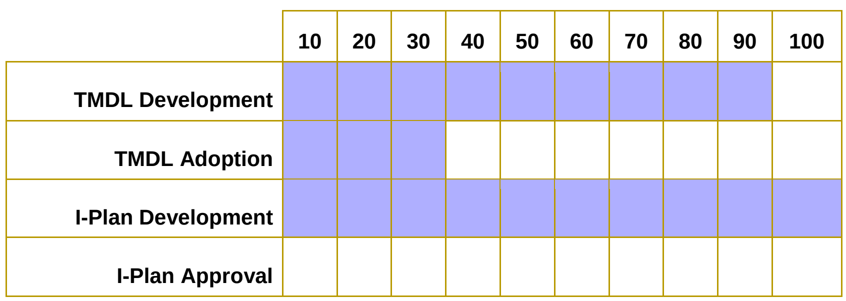
Houston–Galveston Area Council
Aubin Phillips, Environmental Planner
832-681-2524, aubin.phillips@h-gac.com

TMDL Development

Start Date: January 2012
Projected End Date:

TMDL and I-Plan Development: Percent Complete



Highlights

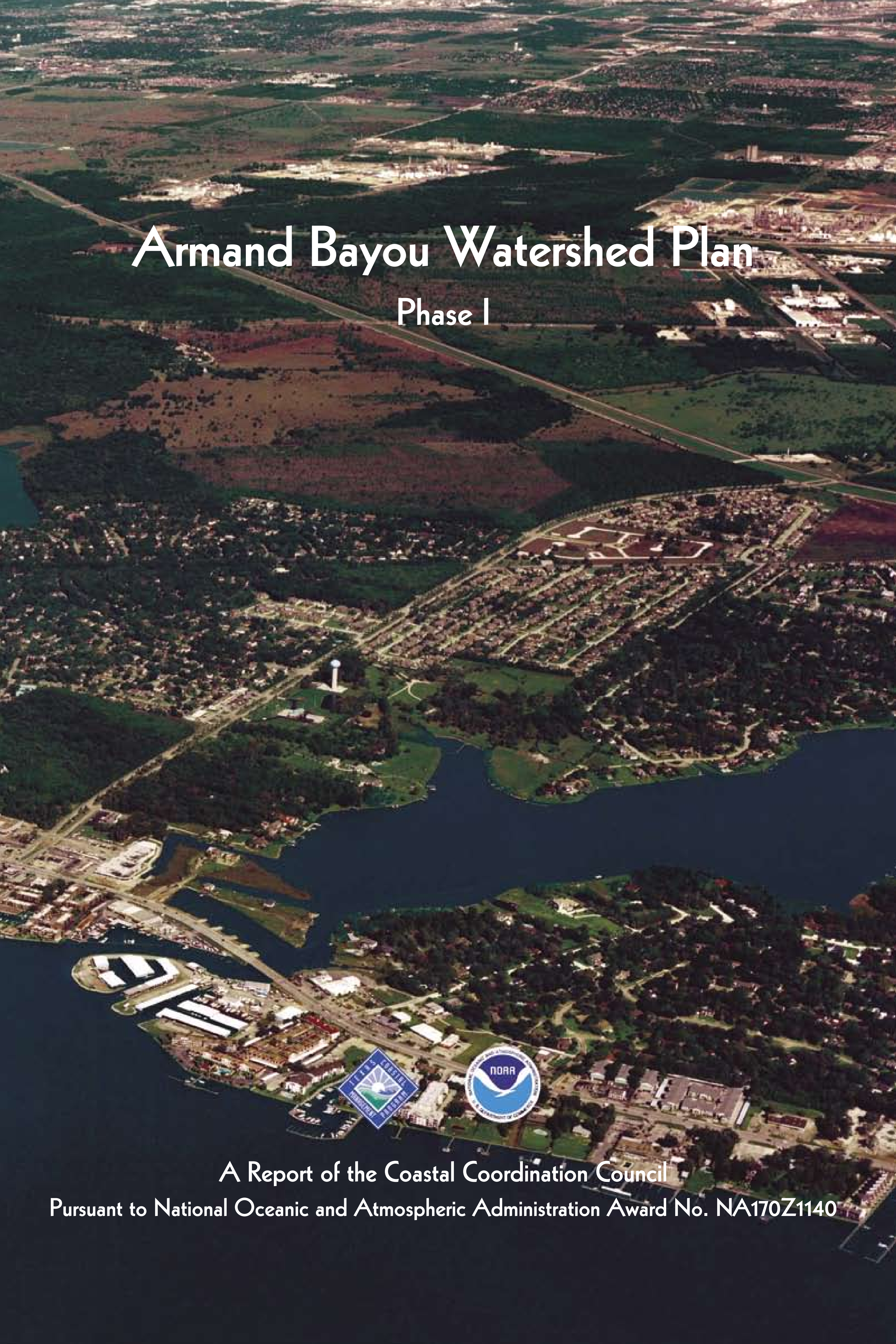
- The Houston–Galveston Area Council (H-GAC) is coordinating public participation in development of this TMDL and its I-Plan.
- In June 2013 the Armand Bayou Coordination Committee voted to petition the BIG to join its I-Plan.
- In May 2014 the BIG voted to accept this petition and include the Armand Bayou watershed in their implementation efforts.

Armand Bayou Watershed Plan

COVER: TOP LEFT PHOTO COURTESY ARMAND BAYOU NATURE CENTER; ALL OTHER PHOTOS © CLIFF MEINHARDT

Armand Bayou Watershed Plan

Phase I



A Report of the Coastal Coordination Council

Pursuant to National Oceanic and Atmospheric Administration Award No. NA170Z1140

Production of this document supported in part by Institutional Grant NA16RG1078 to Texas A&M University from the National Sea Grant Office, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and a grant from ExxonMobil Coporation

PHOTO © CLIFF MEINHARDT

Contents

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Grants in support of the overall Watershed Partnership effort have included: a Texas Coastal Management Program grant from the Coastal Coordination Council and the National Oceanic and Atmospheric Administration, administered by the Texas General Land Office, and an Environmental Protection Agency Clean Water Act Section 319 grant through the Texas Soil and Water Conservation Board.

Armand Bayou Nature Center, the City of Pasadena, the Galveston Bay Estuary Program, and the City of Deer Park have provided meeting space for the Watershed Partnership and its committees.

Major contributors and writers of the Plan included: Linda Broach, Jeff Dalla Rosa, Alecya Gallaway, Lisa Gonzalez, John Jacob, Scott Jones, Mark Kramer, Linda Shead, Andy Sipocz, Holli Swick, Tim Tietjens, Michi Vojta, and Terry Woodfin. Others who contributed to the Plan included: Amy Broussard (for design and production work), Ricardo Lopez (for maps and drawings), Cliff Meinhardt (for providing photographs), John Machol, Carl Masterson, Sarah Metzger, and Ralph Taylor.

The Plan Task Force was the group that coaxed contributions, and reviewed, edited, and otherwise evaluated all the submissions and brought them to a coherent whole: Jeff Dalla Rosa, Lisa Gonzalez, John Jacob, Scott Jones, Linda Shead, and Tim Tietjens.

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We reserve special appreciation for Linda Shead. Her energy and persistence were largely responsible for bringing the Partnership together to complete this project. Thanks, Linda!

Executive Summary

Introduction

Phase I of the Armand Bayou Watershed Plan presents the current state of the watershed, the current management programs and practices, and the current tools and strategies available for achieving the mission of the Armand Bayou Watershed Partnership (Watershed Partnership): **to protect, preserve and enhance the ecological integrity of the Armand Bayou watershed while improving the quality of life in our communities.** Phase II of the Armand Bayou Watershed Plan will build on the Phase I Plan to address implementation of the Watershed Partnership's goals toward accomplishing its mission and realizing its vision.

The Armand Bayou watershed is located in southeast Harris County, mostly east of Beltway 8 and south of Highway 225, draining approximately 59 square miles to Clear Creek. As with most of southeast Texas, the watershed is relatively flat, with land sloping at about one foot per mile, has mostly clayey soils, and receives an average rainfall of 48 inches per year. The habitat in the watershed was once dominated by tall-grass prairie, punctuated by forest corridors along stream channels and flatwood forest across much of the lower part of the watershed.

The watershed has experienced vast changes over the years, especially from agriculture, drainage channels, residential and commercial development, and groundwater withdrawals. Still, examples remain of some of the original topography and vegetation that existed prior to settlement. One notable example of the native prairie and woodlands may be found at the Armand Bayou Nature Center. Some of the original topography of mima mounds and prairie pothole depressions also remain in the lower part of the watershed. The Armand Bayou watershed is a place for people to live and work, but it's also a place to connect with the natural heritage of this region.

The Armand Bayou Watershed Partnership

The Armand Bayou Watershed Partnership (Watershed Partnership) came together because of a shared interest in preserving and enhancing the natural integrity of the watershed through the coordinated management of natural resources. The Watershed Partnership is composed of stakeholders from state and federal agencies, nonprofit organizations, civic groups, academic institutions, local governments, business and industry groups, and utilities.

The vision of the Watershed Partnership includes restoring the ecological function of the bayou and maintaining the natural integrity of the natural resources in the watershed. The vision also includes a watershed populace that is aware of the natural values of this watershed, and that makes choices accordingly. Implementation of this vision will involve improving education and stewardship, working to enhance water quality and protect habitat, and supporting a coordinated decision making process for activities that affect the watershed.

The Watershed Partnership has opted to create a Watershed Action Plan in multiple phases. The first phase establishes the baseline conditions and an initial vision for the watershed. From this first phase plan, the Group will work to establish priorities, create a detailed plan of management options, and implement improvement projects. Group members will evaluate the progress and repeat various stages as necessary, as part of an iterative process.

State of the Watershed

Habitat

In spite of heavy impacts by development over the years, the Armand Bayou watershed retains some very unique and valuable natural areas (i.e., habitat. Lower Armand Bayou is one of very few unchannelized stream segments in the Houston metropolitan area. People throughout the region consider the habitat in this watershed to be one of the most important amenities in the Houston-Galveston area.

Just over half the watershed is in undeveloped or "open" space (about 21,000 land acres and about 1,000 acres of open water). Of that amount, about 14,000 acres could be considered as "significant" (i.e. relatively undisturbed) wildlife habitat, composed of coastal flatwoods, prairie pothole complexes and other prairies, tidal marshes, and the aquatic habitats associated with Armand Bayou and Mud Lake. After the permanent alterations caused by development, invasive plant and animal species are perhaps the next most significant threat to native habitat in this watershed.

Water hyacinth within the bayou and Chinese tallow on the prairies are the two most dominant invasive plants. Channeled applesnails and nutria are among the most problematic animal invasive species. A few significant areas are permanently protected within the watershed, most notably the 2,500 acres associated with the Armand Bayou Nature Center and the 300-acre Armand Bayou Coastal Preserve. Other important opportunities for additional protection may be found within the watershed.

Water Quality

The tidal and above tidal portions of Armand Bayou are currently listed on the state's list of impaired water bodies because of low dissolved oxygen levels that seasonally occur in the Bayou. Seven major fish kills have occurred in the Armand Bayou watershed since 1971; most located in the tributaries. Four were attributed to low dissolved oxygen.

Detrimentally high values of chlorophyll-a, an indicator of algal populations that are a proximate cause of the low dissolved oxygen, has been found in the summer in Armand Bayou and some of its tributaries. The high chlorophyll-a would seem to suggest high nutrient loadings (from lawn and garden fertilizers and wastewater treatment plants) into the Bayou and its tributaries, but none of the water quality studies to date have found elevated levels of nutrients.

Additional problems include high fecal coliform bacteria counts (an indicator of human or animal waste in the water) and relatively high turbidity (or low water clarity). Most local residents note the very deep green color that characterizes Armand Bayou and its major tributaries most summers.

In spite of some real water quality problems, Armand Bayou is not totally degraded. In fact, studies indicate that Armand Bayou has a diverse fish population that is indicative of "good" water quality. But additional development within the watershed threatens to degrade water quality in the Bayou and its tributaries further.

Flooding

The Armand Bayou watershed is prone to flooding because the topography of the area is extremely flat with a slope of less than one foot per mile, and the watershed has an abundance of relatively impermeable clayey soils. Although flooding is a naturally occurring event in the watershed, impacts from flooding have increased because of development and concomitant increases in stormwater runoff into the bayous, and because some construction has occurred within the floodplains. Many of the most impacted residences within the floodplain have, however, been bought out.

Major efforts at providing stormwater "detention" are occurring throughout the watershed. Detention basins hold back runoff water from paved surfaces and release it slowly to avoid flooding.

Public Education and Outreach

One of the main challenges facing the Armand Bayou watershed is how to create a sense of place and community among the residents of the watershed, and an understanding of how watersheds work, so that residents become more effective stewards of the watershed. Several agencies and institutions have educational and outreach programs that impact residents in the watershed, but much more remains to be done.

Institutional Framework

Aside from some limited protection of wetlands by the federal Clean Water Act, very few laws exist that directly protect and regulate usage of natural areas. However, a few unique pieces of legislation have direct local implications, including laws requiring coordinated coastal zone management, regulation of groundwater withdrawals, and consideration of freshwater inflows to bays and estuaries in statewide surface water management.

Several federal, state, and local agencies oversee state resource protection laws, including the Environmental Protection Agency, U.S. Fish and Wildlife Service, Texas Commission on Environmental Quality, Texas General Land Office, Texas Parks and Wildlife, and various groundwater districts. Additionally, numerous local non-profit organizations participate in coordinated natural resource management efforts.

Tools and Strategies

Improving the ecological integrity of the watershed begins with natural open areas or habitat. Although preservation can be an expensive endeavor, various tools are available to conserve natural areas. Restoration and management can bring back disturbed habitats to their pre-settlement ecology, as may be seen at the Armand Bayou Nature Center. A number of nongovernmental organizations and government agencies offer expertise, services, and funding for preservation and restoration of open space.

Impacts to water quality come from a variety of sources, and the tools for water quality improvements are equally varied: preservation of open space, low impact development, wastewater treatment options, stormwater options, and reduced use of toxic products at homes and businesses.

Tools to reduce flood damages are generally either "structural," such as channelization or detention basins, or "non-structural," such as buy-outs or on-site garden or swale features. Strategies for reducing flooding impacts involve stepping back to identify larger scale approaches. These may include ordinances, flooding analysis for prevention, and watershed-wide detention planning.

Almost every organization involved in water, watershed, or water quality work in the Armand Bayou area deals at least tangentially with public education and outreach. However, the efforts are somewhat of a "shotgun" approach, scattered and unorganized, and lacking in a unified education and outreach strategy. Nationally, however, several examples of well-organized outreach programs may be found, as well as organizations dedicated to supporting such efforts.

Monitoring and Measuring Progress

In order to protect watershed health, it is important to monitor the state of habitat and water quality. To account for human interactions with the watershed in regards to flooding, it is also critical to monitor flooding regimes and the pattern of flood damages to the built environment. Finally, to gauge the efficacy of

any watershed plan education and outreach effort, it is necessary to know the level of public environmental awareness.

Information Needed

If the Armand Bayou watershed is to be appropriately cared for and better understood, then the information collected in this plan should be as complete and comprehensive as possible. Better information results in more informed decision-making. Although this plan contains vast amounts of information collected from many sources, it is acknowledged that much is lacking. For example, very little documented information exists about how water moves from prairie pothole wetlands to the bayou. This information could help scientists develop effective plans for restoring existing wetland complexes to their full functionality.

Additionally, while this plan describes the current state of the watershed, it is acknowledged that circumstances, physical conditions, and the availability of information, etc., will change after production of the plan. An example of this circumstance is the FEMA floodplain maps, which have recently been revised to more accurately show the topography of the watershed and the floodplain as a result of the LIDAR study conducted by the Tropical Storm Allison Recovery Project team.

Undertaking additional scientific studies of various types is often a function of the amount of funding available, but the additional information would surely produce a more effective watershed system. Watershed function can only be better understood when data gathering efforts are systematic and comprehensive.

Next Steps

This Phase I Armand Bayou Watershed Plan presents the current state of the watershed, the current management programs and practices, and the current tools and strategies used throughout the watershed. The Phase II Armand Bayou Watershed Plan will build on the Phase I plan to develop a more complete plan that will begin to implement the mission and vision of the Watershed Partnership. The Phase II Plan will identify specific objectives and tasks in ways that build partnerships, coordinate actions, leverage resources, and enhance opportunities for success. Development of the Phase II Plan will involve reaching out further into the watershed community to expand involvement, participation, and stewardship.

The Steering Committee and Watershed Partnership recently adopted formal procedures for their structure and operation to be used throughout the Phase II Plan development process. It will begin with the publication, release, and distribution of Phase I Plan, Executive Summary, and informational brochures. Considerable public outreach will be conducted to promote public awareness and education about the Armand Bayou watershed. The existing subcommittees will continue to operate and others may be added as needed. It is anticipated that the already strong and broad participation will strengthen as the Phase I Plan is publicized and Phase II plans begin to develop. Target dates for milestones and completion of the Phase II Plan will be generated as part of the plan development process.

PHOTO BY STEPHAN MYERS

Mission, Vision, and Goals of the Armand Bayou Watershed Partnership

Mission

To protect, preserve and enhance the ecological integrity of the Armand Bayou watershed while improving the quality of life in our communities.

Vision:

1. The ecological function of Armand Bayou is restored.
2. The watershed's valuable natural resources — its physical and biological integrity — are maintained.
3. All who live and/or work in the watershed are aware of the values of the Bayou to the community and its relationship to the ecology of Clear Lake and Galveston Bay, and understand their role in maintaining its health.
4. Residents, business interests, and decision-makers make choices, individually and collectively, which enhance the watershed's health and minimize negative impacts.

Goals:

1. Improve awareness and understanding of Armand Bayou and its values to the community.
2. Increase stewardship of Armand Bayou and its tributaries.
3. Enhance water quality to minimize fish kills and maintain aquatic diversity in Armand Bayou and its tributaries.
4. Reduce erosion and runoff pollution through measures both in the watershed and along stream banks.
5. Avoid harmful changes in the salinity regime of Armand Bayou.
6. Reduce the impact of flooding on homes and businesses, using the watershed's natural ability to absorb floodwaters wherever possible.
7. Protect and restore valuable habitat areas through the watershed.
8. Protect the riparian and adjacent habitats along the lower reaches of Armand Bayou.
9. Support coordinated decision-making for protection, restoration, and enhancement of Armand Bayou and its watershed.
10. Develop and implement a monitoring strategy to evaluate the effectiveness of watershed protection and restoration methods.

Introduction

This document is Phase I of the Armand Bayou Watershed Plan. It presents the current state of the watershed, the current management programs and practices, and the current tools and strategies available for achieving the mission of the Armand Bayou Watershed Partnership (Watershed Partnership): to protect, preserve, and enhance the ecological integrity of the Armand Bayou watershed while improving the quality of life in our communities.

This Phase I Plan represents the work of members of the Watershed Partnership. They are people who care a lot about the watershed, and come from a broad cross-section of the community. Many are professionals, but all have an interest in watershed management, whether from academia, state and federal agencies, business interests, regional entities, city departments, nonprofit organizations, or citizen residents.

The participants in this process have a vision for the watershed, one that improves the health and sustainability of the natural and built environments. They are concerned about the degradation of water quality in Armand Bayou and its tributaries, about increases in flooding and flood damages, and about the increasing loss of natural habitat. In particular, they are concerned with the lack of coordination among government entities in the watershed. These participants recognize the need for increased education at all levels. They see a need to develop a plan to preserve and restore habitat in the watershed, and to develop the watershed in as sustainable a manner as possible. The Watershed Partnership recognizes that many resources, both regulatory and non-regulatory, are at the disposal of the citizens of the watershed, but that much work will need to be done to coordinate these resources in a way that benefits both people and the environment.

Phase II of the Armand Bayou Watershed Plan will build on the Phase I Plan to address implementation of the Watershed Partnership's goals toward accomplishing its mission and realizing its vision. The Phase II Plan will identify specific objectives and tasks -- incorporating existing management resources, as well as new ones that may be discovered -- in ways that build partnerships, leverage resources, and enhance opportunities for success. Development of the Phase II Plan will involve reaching out further into the watershed community to expand involvement, participation, and stewardship.

Watershed Basics

What is a watershed?

A watershed is the area of land that catches rain and drains into a marsh, bayou, creek, river, lake, or bay. It functions similar to a bowl: Water dropped inside the bowl works its way to the bottom of the basin — draining to a common outlet.

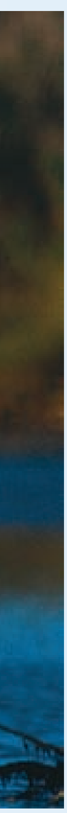
Watersheds

PHOTO © CLIFF MEINHARDT

Why are watersheds important?

Because all watersheds are defined by natural hydrology and ultimately drain to coastal waters, they are good focal points for managing coastal resources. The resource becomes the focal point, and managers are able to gain a more complete understanding of overall conditions in an area and the stressors that affect those conditions.[1] This has been known for some time. John Wesley Powell, who led the first reported expedition down the length of the Colorado River in the mid-1800s, advocated for a "watershed democracy"—for western state boundaries to be established along watershed boundaries.

Everyone lives in a watershed. Even those who don't live near the water live on land that drains to a river, estuary, or lake, and everyone's actions on that land affect water quality and quantity far downstream. Decisions made by homeowners and citizens can affect the quality of the water everyone uses, for drinking, fishing, boating, or swimming. Individual actions—either negatively or positively impacting water quality—may not seem like much, but collectively, they can have a tremendous impact. Watersheds can be large or small. In addition, each watershed can be part of a larger watershed. For example, several subwatersheds are part of the Armand Bayou watershed (Horsepen, Spring Gully, etc), and the Armand Bayou watershed itself is part of the larger Clear Lake and Galveston Bay watersheds.



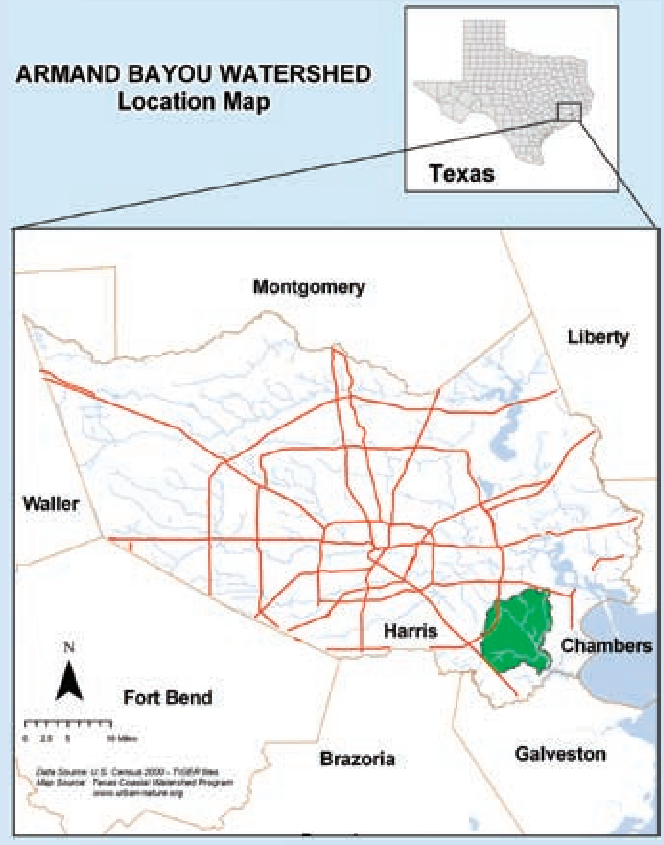
Armand Bayou Watershed Characteristics

Location

The Armand Bayou Watershed is located in southeast Harris County and is entirely in Harris County Precinct Two, situated mostly east of Beltway 8 and south of the La Porte Freeway (State Highway 225). The Gulf Freeway (IH-45) bounds a portion of the basin in the southwest corner. State Highway 146 is roughly two miles east of the basin.

Armand Bayou and its tributaries drain 59.1 square miles (37,822 acres), including portions of the cities of Houston, Pasadena, Deer Park, La Porte, and Taylor Lake Village. The City of Houston and the City of Pasadena compreise the greatest amount of land in the watershed, with 14,079 acres and 12,129 acres, respectively. The upper and lower portions of the watershed have developed residentially. The central portion is industrial to the east and undeveloped agricultural land to the west, with some oil and gas production. The majority of the watershed is already developed, and the balance is developing

[1] EPA "Why Watersheds" brochure (http://www.epa.gov/owow/watershed/why.html)



Location of Armand Bayou Watershed

The Armand Bayou Watershed includes portions of five cities — Houston, Pasadena, Deer Park, La Port and Taylor Lake Village.

Did you know that the widely recognized headwaters of the main stem of Armand Bayou are not the naturally occurring headwaters?

at a rapid pace, with urbanization projected to continue at this pace for the next several years.

The Armand Bayou Watershed is a major tributary system of the Clear Creek Watershed, consisting of natural and manmade channels. The basin is slightly less than one-third the size of the Clear Creek Watershed and has a roughly rectangular shape with an average north-south length of eight miles and width of seven miles.

The headwaters of the Armand Bayou main stem begin just west of Beltway 8 near Spencer Highway and flow in a southeasterly direction for 13.8 miles through Mud Lake (also known as Lake Pasadena) to the confluence with Clear Lake. The major western tributary of Armand Bayou is Horsepen Bayou, and the major eastern tributaries are Big Island Slough, Willow Springs Bayou, and Spring Gully.

In the late 1920s, a channel was constructed to drain a large rural subdivision called Golden Acres, which is located north of Beltway 8 and Spencer Highway. The two-mile channel connected to the northernmost meander of naturally occurring Armand Bayou at a point near Spencer Highway and Space Center Boulevard. Significant portions of the natural headwaters, upstream of that connection, were later re-routed or incorporated into underground drainage systems through developing land.

Topography

The high point in the basin is near the western boundary where the ground is generally 35 feet above mean sea level (MSL), with a few mounds 40 feet msl or slightly higher. In the middle of the watershed, where the major tributaries join the Armand Bayou main stem, the ground elevations are generally 15-20 feet above mean sea level (MSL). Downstream of Bay Area Boulevard, ground elevations are between 10 and 20 feet above mean sea level, averaging 15 feet. Land surrounding the outfall of Armand Bayou into Clear Lake is less than 5 feet above mean sea level. Average overland slope across the basin is 1.0 foot per mile.

At the headwaters of Armand Bayou, the elevation of the flowline (bottom of the channel) is roughly 25 feet above mean sea level (MSL). In the middle of the watershed, the flowline is roughly at sea level. This computes to a fall in the main stem of roughly 6 feet per mile in this reach. Beyond this point Armand's flowline is very irregular, fluctuating between mean sea level and 8 feet below sea level. The tidal limit for the

Table 1. Armand Bayou Major Tributaries

Stream	HCFCD Unit No.	Drainage Area (sq. mi.)	Stream Miles
Big Island Slough	B106-00-00	8.8	7.6
Willow Springs Bayou	B112-00-00	7.1	4.9
Spring Gully	B109-00-00	3.3	1.4
Horsepen Bayou	B104-00-00	19.3	6.5

waters of Armand Bayou is approximately 300 yards downstream of Genoa-Red Bluff Road.

Geology and Soils

The land in the watershed was laid down by the Brazos River some 30,000 or so years ago. The Armand Bayou Watershed is now separate from the Brazos River, which lies fifty miles to the west. Galveston Bay was formed by rising sea levels at the end of the last Ice Age, or about 12,000 to 18,000 years ago, which drowned the confluence of the San Jacinto and Trinity rivers. The physical features we recognize today have been in place since that time.

The Armand Bayou watershed is dominated by moderately or very clayey soils. These soils have a very high shrink-swell potential and are the main reason that so very many houses in this watershed need foundation repair. The clayey soils of the watershed are well suited for pastures, or for cropland if drainage is in place. The low permeability of these soils along with the flat topography resulted in the abundance of natural wetlands observed in this watershed.

Examples of curious features called "mima" (or "prairie" or "pimple") mounds and "prairie potholes" (or "pocks" or "pockmark" depressions) remain within the watershed. These features, present throughout the area and widely noted on older maps, provide interesting micro-variations in topography and habitat. The "mima" mounds are circular to elliptical mounds up to 150 feet in diameter and two to four feet in height from the general ground level. Likewise, the "pocks" are circular to irregular, undrained depressions scattered on the ground surface. The origins of these features are widely debated, but are generally recognized to have their origin in the scars and channels formed by the ancient Brazos River, subsequently modified by wind and biotic forces. They have been largely obliterated by urbanization and cultivation. Many mima mounds were "mined" for their soils for Galveston gardens after the 1900 storm.

Rainfall and Historical Storms

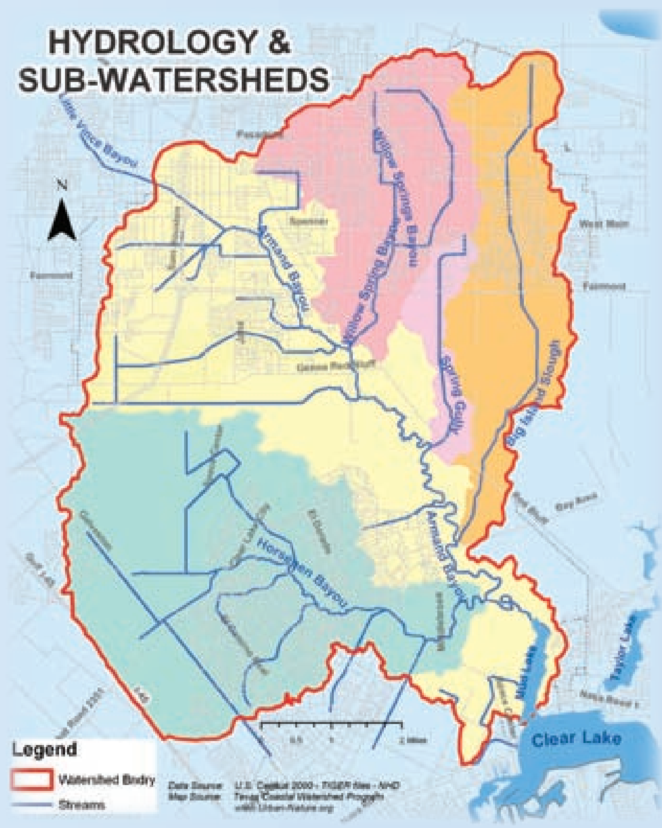
The average annual rainfall within Harris County is approximately 48 inches. Below are rainfall amounts produced by major storms since 1989.

Table 2. Armand Bayou Watershed Selected Historical Storms, 24-Hour Period*

Date	Rainfall Amount(inches)	Comments
06/26/89	10.16	Two-percent (50-year) storm
08/01/89	8.66	Hurricane Chantal
10/17/94	5.75	
10/18/94	5.67	
09/10/98	2.52	Tropical Storm Francis
09/11/98	9.13	Tropical Storm Francis
06/05/01	6.89	Tropical Storm Allison
06/09/01	11.10	Tropical Storm Allison

*HCFCD Gage Number 220, Genoa-Red Bluff Road.

Armand Bayou soils



The streams and bayous that comprise the Armand Bayou watershed.

Habitat

The Armand Bayou watershed lies within the Gulf Coastal Prairies and Marshes eco-region. Prior to settlement in the 19th century, the watershed was largely a tall-grass prairie, characterized by species such as big bluestem and Indian grass. This landscape was maintained by a combination of burning (likely managed by indigenous populations) and low frequency, high intensity grazing by native buffalo as well as Spanish horses and cattle. The prairie was punctuated by forest corridors along the stream channels and by extensive patches of coastal flatwood forests in the lower part of the watershed. Some large and significant tracts of the prairie and woodlands remain in the watershed, most notably at the Armand Bayou Nature Center. Coastal and riparian woodlands are found along Armand Bayou and its tributaries.

Human History and Impacts

Settlement brought vast changes to the watershed, both in terms of vegetation and hydrology. Withdrawal of sub-surface water, for example, has resulted in considerable subsidence in modern times. Most of the land in the watershed has subsided 6-7 feet since about 1900. Switching to surface water has slowed or stopped the subsidence. However, many areas have been affected – marshes drowned and flooding risk increased.

Drainage has always been an issue in the Armand Bayou watershed. Prior to settlement, only the main stem of Armand Bayou and its principal tributaries existed. Drainage in the rest of the watershed was not integrated into these watercourses. Runoff was consequently very slow and wetlands were everywhere. "Improving drainage" has been a constant activity from the very first settlers to our day, and is one of the most significant impacts on this watershed. Human habitation would be extremely difficult in this area without artificial drainage.

Middle Bayou was renamed Armand Bayou in 1974 after Armand Yramategui, the curator of the Burke Baker Planetarium. Yramategui was a grassroots conservationist and political activist who helped bring public awareness to environmental issues in Texas in the 1960s.[2] He was the inspiration for the efforts that resulted in the creation of Armand Bayou Nature Center, preserving 2,119 acres of habitat in the Armand Bayou watershed.[3] Harris County purchased the land and provides a long-term (99-year), rolling lease to the Nature Center.

Farming

The first settlers to the watershed located on the land that bordered Armand Bayou. The area was covered by a riparian forest, accessible only by boat. The sloughs and gullies that crisscrossed the prairies made wagon travel difficult. The farms were mainly small produce farms or family subsistence farms. From the beginning, settlers modified the landscape by providing drainage for their agricultural fields. Large agricultural enterprises did not begin until the railroads began promoting the land in the 1890s. Between 1890 and 1930, farming spread across the watershed. Italian and Japanese immigrants, who came into the area from the period beginning in the 1890s to about 1910, brought about the most agricultural change. Prairies from Red Bluff to Genoa and extending to Ellington Field became rice and sugarcane fields.[4]

After the 1900 Storm, Clara Barton, founder of the American Red Cross, headed the relief efforts and had over a million strawberry plants brought in by train to supply the prairie farmers with a crop that would provide them with quick financial returns.[5] The prairies of Pasadena and La Porte became strawberry fields. Strawberries became an even bigger business in Pasadena when Texaco founder, Joseph S. Cullinan, used the land he purchased

PHOTO BY JACK LEWIS, TEXAS DEPARTMENT OF TRANSPORTATION

[2] Emmott, Sarah, 1985, Who was Armand? Along The Bayou, June/July 1995

[3] Emmott, Sarah, 1985, Who was Armand? Along The Bayou, June/July 1995

as a strawberry farm. For the next sixty years, much of the wet coastal prairies were plowed and hilled for strawberry fields in Pasadena.[6]

Evidence of man-made channels servicing Pasadena and Houston appear on the 1943 edition of the U.S. Geological survey (USGS) quadrangle maps. The early settlers, probably farmers, likely built these channels to help drain the land for cultivation.

Ranching

When the first settlers arrived in the watershed, they found herds of wild cattle and horses, descendants of the Spanish cattle and domesticated cattle that strayed from settlers.[7] Until the late 1890s, cattle comprised the majority of the animals in the riparian and prairie areas of the Armand Bayou watershed.

William Vince received title to a league of land (4,428 acres) on the south side of Buffalo Bayou as one of Stephen F. Austin's first 300 settlers. Today this land is part of the City of Pasadena.

The cowboys on the Allen Ranch of the mid-1800s are credited with naming Horsepen Bayou. One of the sharp meander curves with high banks provided a location to drive the wild horses to trap and pen them. In 1925, James Marion West began buying up property in the Armand Bayou watershed. Within ten years the West Ranch encompassed 30,000 acres.[8] Today, the lands of the West Ranch have become:

- Residential development of Clear Lake City (15,000 acres)
- Bayport Industrial District (10,500 acres)
- Bayport Channel (725 acres)
- Johnson Space Center (1,620 acres)
- West Mansion and surrounding lands (100 acres)
- Armand Bayou Nature Center (2,119 acres)
- Remainder includes oil and gas fields that are also used for cattle grazing

During the 1930s, ranchers were forced to fence their pastures and gather the herds of wild horses from the prairies. Fencing would contribute to the alteration of the watershed's prairies. Underneath the wires, fencerows of shrubs and trees invaded the grasslands, seeded by the myriads of perching birds that lived or migrated through the area. The fragmentation of the prairie by fences reduced the efficacy of one of the most important factors responsible for the character of the prairie: fires set by the native populations to burn large expanses of prairie. The reduction in fire changed the composition of the prairie.

The native tall grass prairie grasses had unfortunately been almost eradicated by overgrazing by the 1890s. During this same period, many exotic plants that have since proved to be invasive were introduced, including grasses, trees, shrubs, vines, and aquatic plants. The Chinese tallow was sold and planted as a popular shade tree by nurseries prior to the 1920s, and has proven to be a major invader of the prairies. Another exotic, water hyacinth, reportedly filled Clear Lake in the late 1920s and 1930s. Saltwater

flooding into the lake during a small hurricane of the 1930s killed it. Cyclical changes in salinity continue to limit the range of hyacinth.

Wildlife, Hunting and Trapping

The watershed was a favored habitat for both large and small mammals. The riparian corridor gave shelter to both predator and prey. Black bear, puma, bobcats, wolves, and coyotes are found in the historical records. Small groups of bison were sighted from Buffalo Bayou to Clear Lake during the 1830s. Deer were plentiful until the turn of the 20th century. During the 1920s Jim West stocked his land with deer and made a portion of his land a game preserve.[9] Local trappers harvested alligators, bobcat, raccoons, beavers, muskrat, otters, fox, skunks, and other small animals for hides. Wild game that was hunted for food, or for trotline bait, included: deer, swamp rabbits, cotton-tailed rabbits, jackrabbits,

[4] C. David Pomeroy, Jr. Pasadena The Early Years, 1993, Pomerosa Press: Pasadena
[5] Barton, Clara, 1900, Report
[6] C. David Pomeroy, Jr. Pasadena The Early Years, 1993, Pomerosa Press: Pasadena
[7] C. David Pomeroy, Jr. Pasadena The Early Years, 1993, Pomerosa Press: Pasadena
[8] Alecya Gallaway, A Lumberman's Empire: The West Ranch, Sept. 1995, Bay Watcher Magazine, Vol. 2, No. 30

PHOTO © CLIFF MEINHARDT

ducks, squirrel, and alligators. Wild animals run by dogs for sport were wolves, coyotes, bobcat, fox, raccoon, and rabbits.[10]

Fishing

Early fishing reports from the 1920s and early 1930s indicate Clear Lake as a near fresh water habitat some of the time, and fish caught there were mostly fresh water catfish, bass, perch, bream, and alligator gar. Blue crabs and bait shrimp were caught in the marshes just inside the channel to Taylor Lake. Before the 1940s, the small shrimp in Clear Lake were only used as bait and were caught with seines and cast nets. By the 1950s, markets had opened up for small shrimp, and Clear Lake was considered a major shrimp nursery grounds. During the 1950s tarpon were caught in Clear Lake all the way to Clear Creek at Webster. Rangia cuneata and Rangia flexuosa clams were the major molluscan species in the lake.[11] Men who regularly fished the area thought the salinity in the lake increased during the late 1940s after the straight channel was cut to the bay.[12]

Recreational Use

Armand Bayou is rich with recreational opportunities. Some of the most important recreational activities that the bayou offers include canoeing, kayaking and rowing. Paddlers find a waterway that has been protected from most of the influences that urban development has brought to other Houston area waterways. The bayou remains one of the last unchannelized bayous in Harris County. Most of the mid and lower length of the bayou is lined with a coastal flatwood forest. This convergence of the forest and bayou habitats offers paddlers the possibility of viewing numerous forms of wildlife. Perhaps most significant to paddlers is the restriction against gasoline motors: The use of gasoline-powered motors is prohibited north of Mud Lake. This restriction creates a paddling atmosphere that is calm and quiet. Many paddlers enjoy fishing as they float through the preserve. The bayou offers a great diversity of sport fish species to pursue including channel catfish, blue catfish, largemouth bass, bluegill, grass carp, redfish, speckled trout, and flounder. The relative calm of the preserve, the abundance of wildlife, and the close proximity of the preserve to town make Armand Bayou one of the most popular recreational destinations in the Houston area.

Houston Canoe Club members have been paddling and conducting trips on Armand Bayou since at least 1964, including, in early years, a Cruise with the Blind. An estimated 50-100 club members participate in organized trips each year. With the canoe put-in site at Bay Area Park, originally a muddy place, club members obtained permission to build a boat pier in the mid 1970s. Materials were donated, and club members spent two days pounding posts and installing the structure. The County is investigating improvements to the area, which had fallen into disrepair.

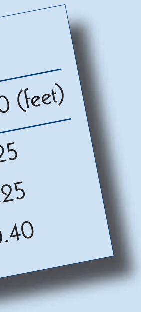
Located along both shorelines of the southern portion of the bayou lies the Armand Bayou Nature Center (Nature Center). Created in 1976, the Nature Center has a two-fold mission statement of providing environmental educational opportunities

Table 3. Armand Bayou Watershed Land Surface Subsidence

Region	1906-1978 (feet)	1978-1987 (feet)	1987-200
Upper	8.5	0.25	0.2
Middle	7.0	0.25	0.
Lower	5.0	0.50	0

[9] Dallas Coons, ABNC oral history, 1977
[10] Dallas Coons, ABNC oral history, 1977; also Louis Muecke, ABNC oral history; also Don Dick, 1998, Dick family interviews, Alecya Gallaway collection
[11] Buzz Larrabee, Shrimping history interviews, Alecya Gallaway Collection; also NMFS reports, 1958-1962; also Tony Muecke, ABNC oral histories.
[12] Dallas Coons, ABNC oral history, 1977; and Galveston District Army dredging records in Clear Lake, 1948.

TOP PHOTO © CLIFF MEINHARDT; PHOTO AT RIGHT BY STEPHAN MYERS



to the public and preserving the land under its care for this and future generations. Recreational activities offered at the center include guided forest and prairie hikes, guided canoe tours, birding walks, and star parties. Additionally, the Nature Center provides guided tours of the bayou from the electric pontoon boat, the Bayou Ranger. The Bayou Ranger provides a relaxing venue to observe numerous inhabitants of the preserve including white tailed deer, river otter, American alligator, and more than 220 species of birds.

The Galveston Bay Foundation conducted educational canoe trips on Armand Bayou for adults and families from 1993 to 2002, and for youth from 1997 to 2002. More recently, the Artist Boat has offered eco-art adventures on the Bayou, combining science and art education.

The Houston Canoe Club began coordinating annual spring volunteer clean-ups of Armand Bayou in the 1980s. Later, Nature Center became involved, and this site became part of the regional Trash Bash effort in the mid 1990s. Typically, 200-300 people participate each year, half in boats on the water, and half on land. Corporate and education sponsors are active in the event. An estimated 50-100 club members participate in organized trips each year on Armand Bayou, and many other individuals paddle on private trips. Several area outfitters and canoe/kayak instructors use the bayou for teaching purposes, with students often returning to paddle with their new skills.

Timber

The riparian corridor along the bayou supplied all of the heating, cooking and building materials for the early settlers. Many of the early settlers were boat builders. They bought milled cypress wood cut from the San Jacinto and Trinity rivers to build the exteriors of their boats, but depended on the "water woods" like mulberry and overcup oak to build the boats ribs. Masts were made from pine, and live oak, and cedar was used on the interiors.[13] Spanish moss was harvested for stuffing bed mattresses and was cured and made into horse blankets by some of the early settlers.

Ground Water Withdrawal and Subsidence

Prior to the 1920s producing wells could be dug by hand to the shallow, 15- to 20-foot, water sands. Deep wells or artesian wells were dug at Pasadena, Genoa, La Porte, and Seabrook and as irrigation wells for the rice fields.[14]

Like other areas in Harris County, the Armand Bayou watershed has experienced a gradual lowering of the ground's elevation, over the past several decades, primarily due to withdrawals of groundwater for industrial and municipal use. Maps prepared for the Harris-Galveston Coastal Subsidence District show that the local cone of subsidence (the central point of most

[13]Porter family interviews, Alecya Gallaway collection; also Louis Muecke, ABNC oral histories.
[14]Harris County Ground water records

subsidence) from 1906 to 1978 was located slightly northwest of the watershed's northern boundary. Historical rates of subsidence are shown in Table 3.

The rate of subsidence was about one foot every nine years in the upper and middle regions of the watershed until the subsidence plan kicked in around 1978. After implementation of the plan began, the rates dropped to 0.25 feet in both the upper and middle regions for the next nine years. Since 1987, the rates in the upper and middle regions dropped to 0.17 feet every nine years. In the lower basin, the subsidence rate up to 1978 was not as severe as in the upper regions, and the reduction in subsidence since then has been less pronounced, though still declining.

Because the upper part of the watershed experienced more subsidence than the lower, the slope (gradient) of the stream has flattened, thus increasing the potential for flooding.

Oil, Gas, and Other Industrial Use

The Clear Lake oil and gas field and pipelines occupy part of the watershed and are part of the vast oil and gas production facilities of the lower Galveston Bay watershed. Included are platforms for producing oil and condensate, and natural gas, plus the pipelines for their transport. Additionally, the petrochemical industry is a major presence in the Armand Bayou watershed, through the facilities in the Bayport Industrial District. The petrochemical industry in the entire Galveston Bay watershed comprises nearly fifty percent of the chemical production in the nation, a major economic engine for the region.

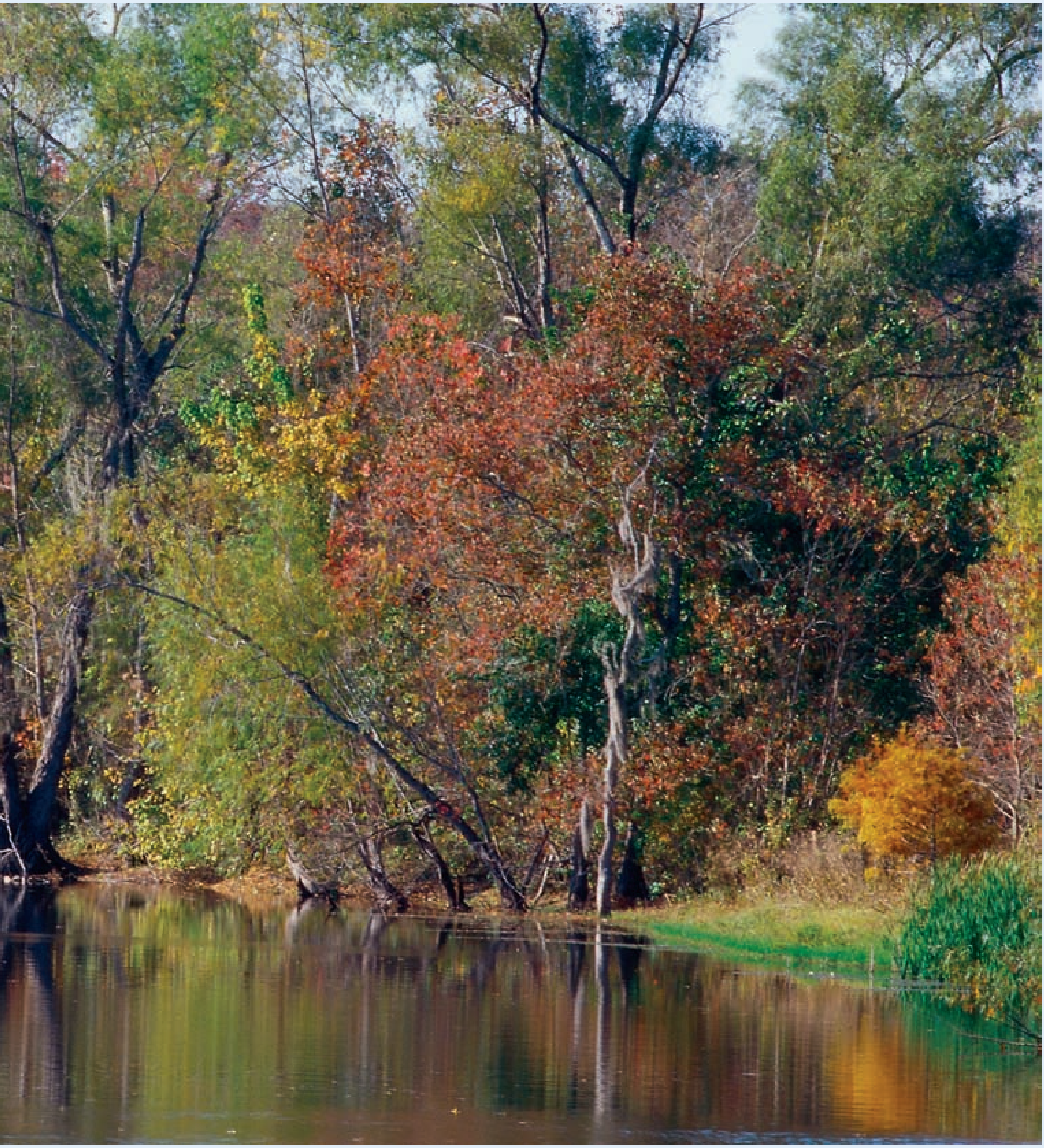
Impacts on the environment from oil and gas production have included the results of the unintentional discharge of petroleum and of the formerly common practice of discharge of produced water (water associated with the oil and gas in the subsurface formations) into streams near production facilities. In 1998, the USEPA developed and implemented regulations that prohibited the discharge of these produced waters, which contained hydrocarbons and a salt chemistry that is different from the natural streams and bay. Both the hydrocarbons and the salts had deleterious effects on marine life.

The petrochemical industry also has impacts on the Armand Bayou watershed through the discharge of stormwater from plant facilities. The process wastewater from these facilities is treated and discharged in adjacent watersheds.

Residential and Commercial Development

Development began first in the upper part of the watershed. Pasadena, Deer Park, and La Porte were all founded around the turn of the last century, although real development from these cities did not reach into the watershed until the 1940s and 50s. Development in the lower part of the watershed did not begin until the 1960s with the advent of NASA. In addition to destroying natural habitat, development radically alters the natural hydrology of the land. Buildings and pavement ("impervious" surfaces) keep rainwater from infiltrating into the soil and replace natural vegetation and wetlands, resulting in very rapid, and often polluted, runoff.

PHOTO © CLIFF MEINHARDT



The Armand Bayou Watershed Partnership

History

The Armand Bayou Watershed Partnership (Watershed Partnership) came together because of a shared interest in preserving and enhancing the natural integrity of the watershed through the coordinated management of natural resources. Local, state, and federal resource agencies and institutions share this interest explicitly through their responsibilities and activities in the watershed. The Watershed Partnership believes that all users in the watershed, including residents, industries, business, and development groups, share this interest implicitly.

Two overlapping groups formed the genesis of the Watershed Partnership (originally known as the Armand Bayou Watershed Working Group). In early 1998 Texas Cooperative Extension and Texas Sea Grant, operating under a USEPA Section 319 Water Quality Grant (Clean Water for Armand Bayou), brought together a group of interested stakeholders to address watershed health concerns. At about the same time, the Houston-Galveston Area Council was contracted by the Texas Commission on Environmental Quality to conduct stakeholder meetings for a Total Maximum Daily Load (TMDL)[15] that was to be conducted on Armand Bayou. Because both the stakeholders and much of the focus for both projects was almost identical, the two groups coalesced and began meeting together. The TMDL issues were handled by a subcommittee of the larger Watershed Partnership. As of this writing, the Armand Bayou TMDL is "inactive pending further data."

The Watershed Partnership met frequently during 1998 and 1999. The Watershed Partnership held training sessions on water quality, water quantity (supply), flooding, habitat, and urban growth/demographics as part of a "collaborative learning" process that was instituted with the help of the Bush School of Government at Texas A&M University. A list of priority issues was developed as part of this process. The oversimplified diagram of the complex interactions occurring in the watershed was developed as part of this process. (See Figure 3.)

With new funding support, Texas Sea Grant Extension began reconstituting the Watershed Partnership in November 2002, resulting in this Phase I of the Armand Bayou Watershed Plan.

Organization

Subcommittees operating under the aegis of the Watershed Partnership carry out most of the detailed work of the Watershed Partnership, drawing from group members and technical advisors. Four subcommittees are currently constituted: Habitat, Outreach and Education, Water Quality, and Flooding and Stormwater Management. Task forces may be formed on specific projects, such as the Plan Task Force that helped write and assemble this plan document.

[15]Total Maximum Daily Load. A procedure under the Clean Water Act for assessing and allocating pollutant loads for water bodies not meeting water quality standards.

PHOTO BY STEPHAN MYERS

Technical advisors are drawn from member organizations, other stakeholders in the watershed, and other agencies with expertise/ interest in the watershed.

The physical boundaries that govern the Watershed Partnership are those of the watershed. The programmatic boundaries are those that envelop water issues – quality, flooding/stormwater management, and habitat – and community involvement issues – outreach, education, and stewardship. The Watershed Partnership does not directly consider enforcement issues.

As a collaborative effort, the Watershed Partnership relies on the insights, expertise, and input of the broad spectrum of the Armand Bayou watershed community. Anyone sharing the mission and vision of the Watershed Partnership is welcome and heartily encouraged to participate.

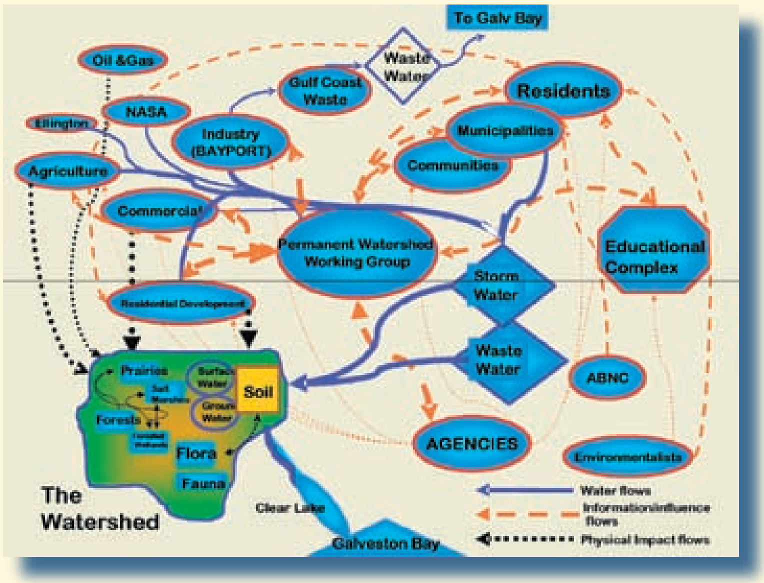


Figure 3. Armand Bayou Dynamic Interactions Diagram developed by the Armand Bayou Watershed Partnership captures a portion of the complexity of the interactions of the watershed.

Mission, Vision, and Goals

Mission

To protect, preserve and enhance the ecological integrity of the Armand Bayou watershed while improving the quality of life in our communities.

Vision

1. The ecological function of Armand Bayou is restored.
2. The watershed's valuable natural resources – its physical and biological integrity – are maintained.

3. All who live and/or work in the watershed are aware of the values of the Bayou to the community and its relationship to the ecology of Clear Lake and Galveston Bay, and understand their role in maintaining its health.
4. Residents and business interests make choices, individually and collectively, that enhance the watershed's health and minimize negative impacts.

Goals

1. Improve awareness and understanding of Armand Bayou and its values to the community.
2. Increase stewardship of Armand Bayou and its tributaries.
3. Enhance water quality to minimize fish kills and maintain aquatic diversity in Armand Bayou and its tributaries.
4. Reduce erosion and runoff pollution through measures both in the watershed and along stream banks.
5. Avoid harmful changes in the salinity regime of Armand Bayou.
6. Reduce the impact of flooding on homes and businesses, using the watershed's natural ability to absorb floodwaters wherever possible.
7. Protect and restore valuable habitat areas through the watershed.
8. Protect the riparian and adjacent habitats along the lower reaches of Armand Bayou.
9. Support coordinated decision-making for protection, restoration, and enhancement of Armand Bayou and its watershed.
10. Develop and implement a monitoring strategy to evaluate the effectiveness of watershed protection and restoration methods.

The Watershed Approach

Groups from across the nation have formed—sometimes prodded by governmental legislation, sometimes spontaneously—to protect and improve their watersheds. Their goals and methods vary widely, but all recognize people's impact upon their watersheds and that coordinated efforts are needed to better utilize the limited resources, both human and monetary. Hence, the "watershed approach" developed.

The watershed approach is "a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow."[16] Its guiding principles are that (1) the people who are most affected be involved in the process, (2) the effort be geographically based, i.e., within the watershed, and (3) sound management, based on strong science and data, in an iterative decision making process to improve the watershed.

Following this process, the Watershed Partnership has opted to create a Watershed Action Plan in multiple phases. The first phase establishes the baseline conditions and an initial vision for the watershed. While extensive information on the Armand Bayou watershed prior to major settlement does not exist, substantial data on the watershed's current conditions and recent history have been collected. This plan also lists the mission, vision, and goals of the Watershed Partnership. From this first phase plan, the Watershed Partnership will work to establish priorities, create a detailed plan of management options, and implement improvement projects. Group members will evaluate the progress and repeat various stages as necessary—again, this is an iterative process.

PHOTO BY STEPHAN MYERS

[16] EPA Watershed Approach brochure (http://www.epa.gov/owow/watershed/

State of the Watershed

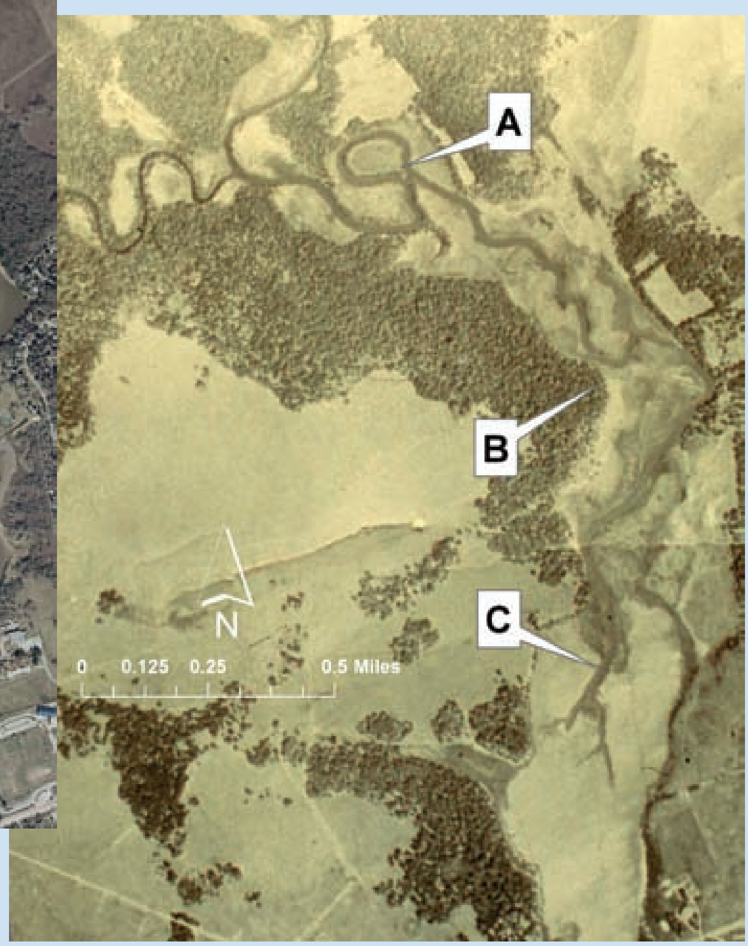
The Armand Bayou watershed has experienced substantial changes, both in a geologic time frame of 30,000 years, and in a historic time frame related to human habitation. This Phase I Plan presents what is currently known about the watershed and the results of these influences, in terms of habitat, water quality, flooding and stormwater management, and public outreach and education.

The Phase II Plan will build on the Phase I Plan to address implementation of the Armand Bayou Watershed Partnership's (Watershed Partnership) goals toward accomplishing its mission and realizing its vision of a protected and enhanced watershed. In developing the Phase II Plan, the Watershed Partnership will work to establish priorities, create a detailed plan of management options, and implement improvement projects. Thus, the Phase II Plan will include specific action items to achieve the Watershed Partnership's goals. Some examples of possible actions are included in the discussions below.

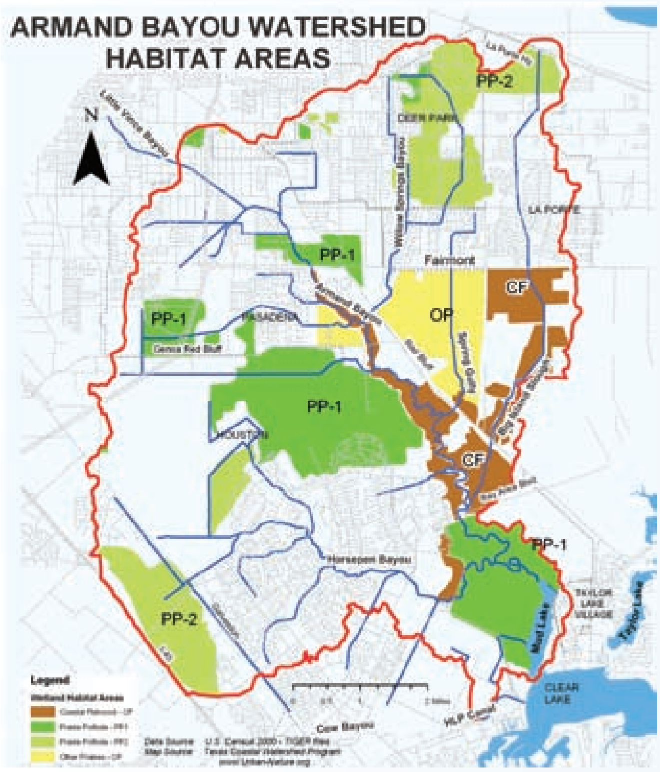
Historical Perspective on the Physical and Hydrologic Nature of Armand Bayou

The region where the Armand Bayou watershed lies is a flat plain lying 10 to 30 feet above sea level and occupying the west shore of Galveston Bay. This plain developed over the last 30,000 years by the buildup of sediments carried to the coast largely by the Brazos River. As the Brazos slowly shifted southwestward, it left behind a gently undulating plain made up broad low areas that lay between higher riverbank deposits.

A large proportion of the region's rainfall runoff flowed to the coast via sloughs and streams. Thousands of circular ponds were formed through the reworking of linear fragments of the ancient river channels, or through wind erosion "blow outs" within the silt and fine sand deposits of the ancient alluvial levees. Very near the coast, long winding intact fragments of the channels remain. Prior to drainage and development, approximately one-third of the region supported wetland vegetation.



Comparison of aerials taken in 2002 (above) and 1953 (right) show the changing topography in the Armand Bayou watershed.



Armand Bayou watershed habitat areas

In addition, many bayous and tidal embayments, which were formed when sea level was lower during the last ice age, pierce from the Bay into the coastal plain. The streams that originate in this region and meandered towards the Bay first began as shallow, marshy swales draining the marsh-dotted tall-grass plain. As they approached the Bay, they usually cut down relatively abruptly to sea level, forming ever-widening, winding tidal channels with steep banks, and would at some point join up with the larger tidal embayments or bayous. Armand Bayou is one of the largest of these and empties into Mud Lake, which flows to Clear Lake, and thence to Galveston Bay.

Habitat

In spite of heavy impacts by development over the years, the Armand Bayou watershed retains some very unique and valuable natural areas or habitat.[17] Lower Armand Bayou is one of very few unchannelized stream segments in the Houston metropolitan area. People throughout the region consider the habitat in this watershed to be one of the most important amenities in the Houston-Galveston area.

The natural areas of the Armand Bayou watershed are much more than just beautiful areas to enjoy. These areas provide a variety of services that come without cost, but which cost dearly when the natural areas are gone and the lost services must be replaced. Depressional wetlands, i.e. prairie pothole wetlands, in the watershed, for example, provide flood detention. In the Armand Bayou watershed, prairie pothole wetlands provide at least 3,000 acre-feet of detention,[18] over and above the natural storage of the native soils in the area.

Natural features in the watershed also act to clean runoff. Rainfall that falls on natural areas soaks into the ground or is slowed and filtered as it courses through vegetation. Without the natural prairie pothole wetlands, much of the rainfall now ends up as runoff. The fraction that soaks into the ground continues to help recharge underground aquifers and helps to maintain a constant flow of water into the bayous and bay.

The natural areas of the watershed are critical habitat for a variety of wildlife that still exists in this area. The Armand Bayou Nature Center, for example, …

> "is home to more than 370 species of birds, mammals, reptiles, and amphibians including white-tailed deer, armadillo, swamp rabbits, bobcats, coyotes, turtles, alligators, frogs, and venomous and non-venomous snakes. Over 220 species of birds reside or rely on the Nature Center as a safe resting place on their long migratory journeys. [The Nature Center] lies along the Central Flyway, which is the largest migratory bird route in North America. … The vegetation of Armand Bayou is characteristic of the East Texas coastal plain. The bayou lies in a biological transition zone between the southern mixed hardwood forest, the coastal prairie, and the coastal salt marshes. The site contains the remnants of one of the few remaining native prairies, small areas of shallow, brackish marshlands, and bottomland hardwood or riparian woodland areas. These areas are historically and ecologically important and require constant efforts in preservation and restoration."[19]

Species lists are provided in Appendix E. Many of these lists were developed from range maps of the species, and all of the species have not necessarily been observed and documented in the watershed. These distinctions between sources of data are noted in the lists.

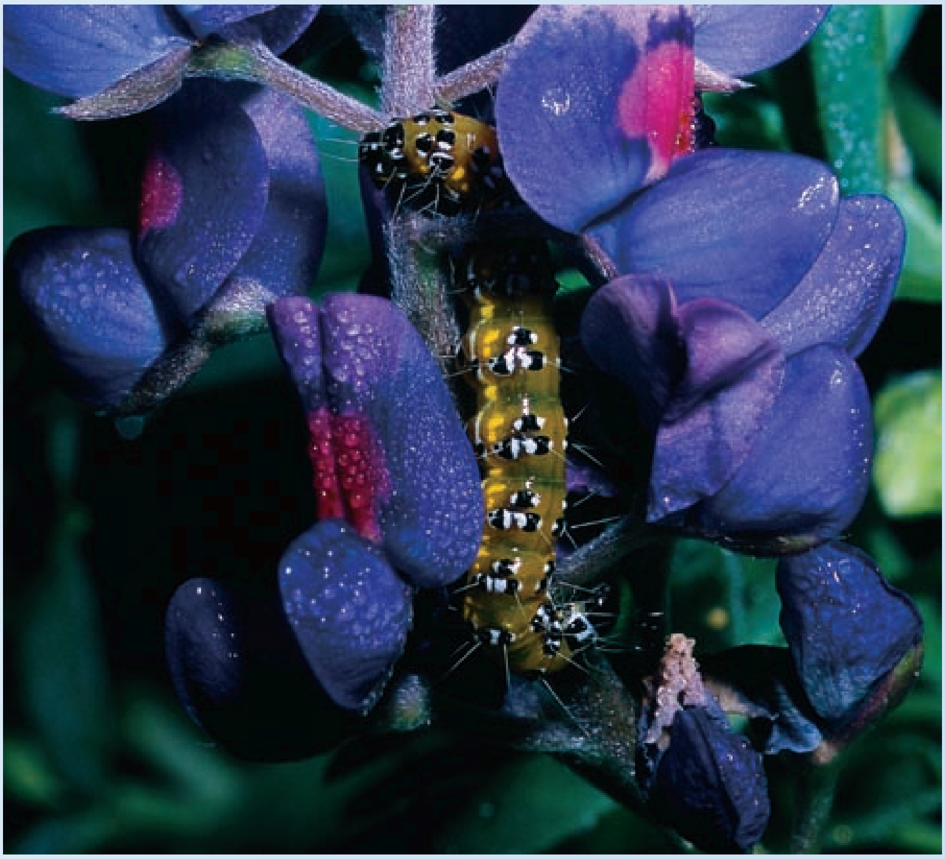
Because of the goods and services provided by natural areas, it is entirely appropriate to refer to them collectively as part of our "green infrastructure." It would be very difficult to live and do business without the "gray" infrastructure of roads, electric power grids, etc. Lack of green infrastructure in this watershed could likewise cause serious disruptions (vastly increased flooding, for example). Green infrastructure can save money by providing ecological services that would be expensive to replace by gray infrastructure. Green infrastructure also improves the quality of life for area residents.

Armand Bayou, like many of the larger bayous, is lined with forest along its lower reaches. Forestlands are usually associated

[17]Habitat refers to natural areas that are suitable for wildlife, and that retain at least some of their natural character. The terms "habitat" and "natural areas" are used interchangeably in this document. Open space refers to any undeveloped area and includes natural habitat as well as parks and pastures.
[18]9,000 acres of prairie pothole habitat in the watershed, which is about 30% depressional wetlands, with about 1 ft average depth.
[19]Armand Bayou Nature Center website (http://www.abnc.org)

with ancient and modern stream drainages. Today almost all, if not all, of the broad marshy valleys of the watershed have been drained. Almost all or all of the marshy sloughs and wide, shallow bayous have been converted into ditches above the tide, including Armand Bayou.

Many of the tidal portions of the bayous have also been channelized, though the lower portion of Armand Bayou has thus far escaped this flood control measure. It contains one of the longest unchannelized stretches of bayou in the region. In addition, it still hosts large areas of upland prairie, riparian forest, and bottomland and flatwood hardwood forests.



Terrestrial Habitats

The Armand Bayou Habitat Map (Figure 3) shows three habitat types for the watershed:

Coastal Flatwoods are woodlands or forests with a dominant overstory of willow oak. Understory plants include palmettos and wood oats. Included in this classification are narrow bands of riparian floodplain forests along the lower reaches of Armand Bayou and Big Island Slough. These riparian forests are characterized by elms and ashes.

Prairie Pothole Complexes are prairies characterized by depressions called potholes and small knolls called mima or pimple mounds. This category is further subdivided by relative preservation of potholes and pimple mounds: PP-1 for excellent preservation and PP-2 for moderate preservation. Undisturbed grassland vegetation of the coastal prairie pothole complexes consists of big bluestem, little bluestem, gamagrass, Indiangrass, switchgrass, etc. Few areas in the watershed have large expanses of this "tallgrass" prairie grasses left, but significant patches of these grasses can be found in the watershed.

Other Prairies are mainly clayey prairies without the pimple-mound complexes.

Just over half the watershed is in open space (about 21,000 land acres and about 1,000 acres of open water). Of that amount, about 14,000 acres could be considered as "significant" habitat (i.e. relatively undisturbed).

For natural areas to be functional, either as "green infrastructure" or as habitat for wildlife, size and continuity of individual areas becomes very important. In simple terms, the larger the area, and the more connected to other areas, the better it functions. Most wildlife has some very specific areal requirements for sustainable habitat. Wildlife habitat in the Armand Bayou watershed has long been depleted well below the minimum requirements for bears and other large species (which may need up to a few thousand acres per animal). Yet, enough contiguous wildlife habitat is still present to support deer, bobcats, hawks, and similar species.[20]

How much land would be required to sustain a fully functioning Gulf Coast Prairie ecosystem is not known, but given that larger mammals, such as bears, require well over 7,000 acres to thrive,[21] a good guess might be in the range of at least 10,000 acres in a single patch. No single, contiguous habitat fragment in this watershed approaches this figure, but a few fragments between 1,000 to 2,500 acres with important ecological functionality remain. A number of habitat fragments in the 300-600 acre range also may be found in the watershed.

The value of small habitat fragments increases greatly if they are interconnected by habitat "corridors." The functionality of these corridors increases as their widths increase, but even narrow corridors can be important. A fair amount of connectivity remains between the habitat fragments of the watershed. A little planning could insure this connectivity remains in place and is even increased.

Aquatic Habitats

The Armand Bayou watershed is home to several aquatic habitat types, including open water habitat of the freshwater to brackish bayou and the emergent marshes found within it. These marshes historically filled Mud Lake and virtually disappeared when

[20]Biederman, Robert. 2003. Body size and area-incidence relationships: Is there a general pattern? Global Ecology and Biogeography. 12:381-387.
[21]Ibid.

PHOTO © CLIFF MEINHARDT

subsidence resulted in the drowning of these habitats within the last 50 years. In recent years, the Nature Center and partners have restored approximately twelve of these habitats. The narrow strips of restored wetlands are too small to be shown on the map.

Salt marsh communities are found in the lower reaches of the bayou in high salinity areas. Prevalent species include smooth cordgrass and marsh elder. Brackish marsh inhabits the transitional zone between salt marsh and fresh marsh and is affected by variations in water levels and salinities. In general, the brackish marsh is dominated by marshhay cordgrass and saltgrass. Fresh marshes are primarily found in upper reaches of the bayou that are affected by saltwater flooding only during large tropical storms or hurricanes. The fresh water in these marshes is sufficient to maintain a low salinity suitable for such species as marsh millet (or giant cutgrass), coastal arrowhead, and squarestem spikesedge.

The emergent marshes present in Armand Bayou and its tributaries serve as nursery and forage areas for a number of aquatic organisms from different levels of the food chain. Several commercially and recreationally important species are found in the bayou as well. Species of finfish and shellfish found in Armand Bayou include brown shrimp, freshwater goby, mosquitofish, gulf killifish, sailfin molly, sheepshead minnow, tidewater silverside, striped mullet, pipefish, Atlantic croaker, catfish, and spotted seatrout.

Armand Bayou likely featured submerged aquatic vegetation in areas of shallow, sandy flats. Subsidence and turbidity associated with human activities have eliminated any naturally occurring beds. Nature Center planted Widgeongrass (Ruppia maritima), a species of freshwater tolerant submerged aquatic vegetation, in several apparently suitable areas recently, but these attempts have been largely unsuccessful. Whether physiological conditions, substrate quality, depredation from exotic herbivores, or other factors caused the failures of these restoration efforts is unknown.

Species lists are found in Appendix F.

Invasive Species

Several invasive species are currently found in Nature Center, several of which have caused ecologically significant problems, and others are expected to create future problems. Water hyacinth, hydrilla, and other invasive aquatic plants have created serious problems in freshwater reaches in the Bayou itself, while elephant ear and other emergent plants have displaced productive native wetland plants that serve as important sources of food, substrate, and shelter along the Bayou's edge. Giant salvinia, a devastating aquatic weed, has been found in local water bodies, and presents a potential threat to Armand Bayou. Deep-rooted sedge is an extremely aggressive emergent freshwater wetland plant. This sedge is likely to have already established local populations within the Armand Bayou watershed. These aquatic plants are difficult to control and can cover the water's surface, shading submerged vegetation.

Among invasive aquatic fauna found in the watershed, channeled applesnails are herbivorous gastropods native to South America. The applesnails are recent invaders that tolerate a variety of salinities and can decimate aquatic vegetation. They are also thought to serve as a vector of disease and parasites. They are suspected of destroying restored widgeongrass beds in the Bayou, and scientists are concerned that this prolific herbivore will cause substantial damage to freshwater vegetation in coming years.

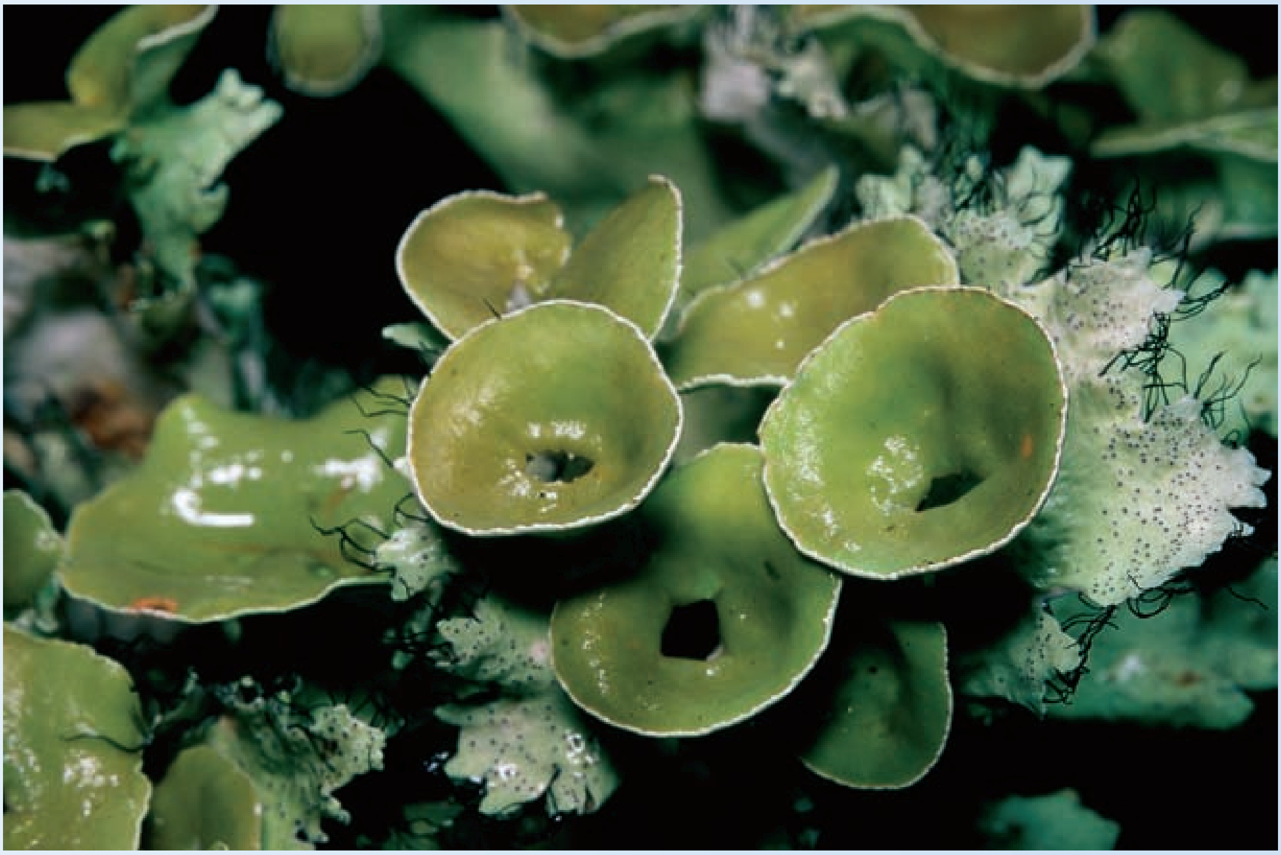
Terrestrial invasives in the watershed negatively impact coastal prairie and flatwood habitats by displacing native vegetation and radically altering the overall habitat, oftentimes faster than the native fauna can keep up with. The Chinese tallow tree is a prominent example of an invasive tree that can completely overtake and change native habitat. Introduced in the area in the 1920's, this tree has completely taken over thousands of acres of native coastal prairie, displacing native flora and disrupting native fauna. In addition to impacts on wildlife, invasive Chinese tallow woods likely alter the hydrologic balance in the area. The tallow trees transpire much more soil moisture than the native grasslands and thus may decrease underground freshwater inflows into Armand Bayou and its tributaries. Other species of invasive plants, such as vasey grass, elephant ear, and Chinese privet, also out-compete native vegetation.

Species of terrestrial invasive animals include the fire ant and feral hog. Fire ants impact ground nesting bird populations, while feral hogs, through their rooting behavior, can leave areas devoid of vegetation, robbing terrestrial natives (e.g. white tailed deer) of their food supply. Nutria is a species of herbivorous rodent native to South America, which has caused extensive damage to wetlands in Louisiana, and is found in the Armand Bayou watershed.

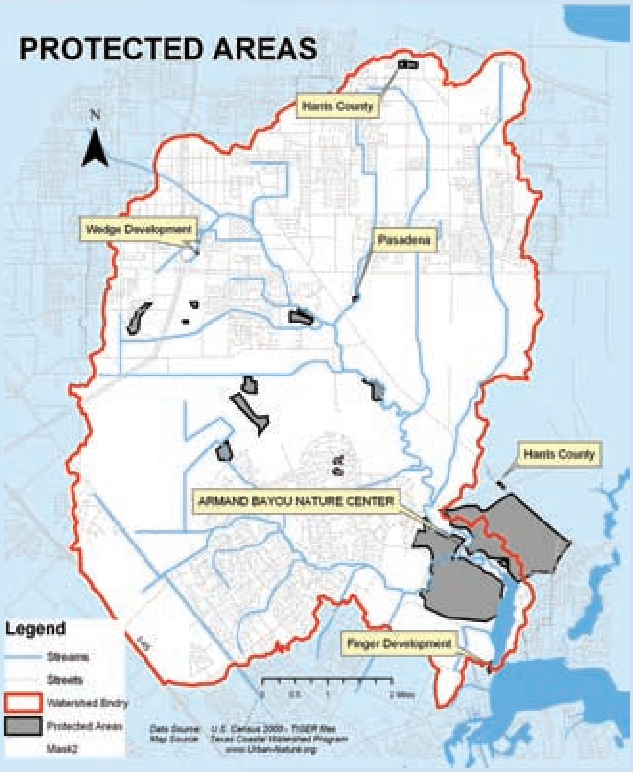
All of these species impact native plants and animals directly or indirectly. Control of invasives is costly in terms of necessary human and monetary resources. The losses to habitat that result can be irrevocable if the species are allowed to spread unchecked. Resource managers and concerned citizens are waging a prolonged battle against invasive species in the watershed. Nature Center staff and volunteers implement range management techniques such as the bush-hog and controlled burns to contain the spread of Chinese tallow in its prairies. The Galveston Bay Estuary Program and the U.S. Fish and Wildlife Service have partnered with the Nature Center to reclaim dozens of acres of historic prairie areas converted to tallow forests, and to control hydrilla in the bayou. Serious resource constraints hamper the ability of managers to protect the biological integrity of the Nature Center against the effects of invasive species. This is compounded by the fact that few state- and nationally-funded programs geared specifically toward the control and prevention of invasive species exist. However, given the ecologic and economic impacts of invasive species, control and prevention will likely continue to rise as a priority. To balance these impacts, resources dedicated to these ends will need to rise as well.

Protected Lands

While most of the natural areas in the watershed are subject to loss through development, a few significant areas have been protected. Only a few private landowners with extensive open



space landholdings in the watershed remain. Kinder-Morgan, which currently owns a gas complex in the center of the watershed, is one of the largest. Exxon Pipeline and Exxon Production also own significant holdings in the watershed.



Armand Bayou watershed protected lands

Armand Bayou Nature Center

Armand Bayou Nature Center (Nature Center) is one of the largest urban nature preserves in the country, and protects 2,500 acres. The preserve was established in 1974. The land is owned by Harris County, but is leased to the Nature Center through a 99-year lease. Although no conservation easement or other mechanism for permanent preservation is in place, the lease contract contains clauses to allow the lease to rollover indefinitely, and ABNC would keep the land open.

Armand Bayou Coastal Preserve

The Armand Bayou Coastal Preserve is one of just four Coastal Preserves along the Texas Gulf Coast. This preserve consists of about 300 acres mainly confined to the main channel of Armand Bayou. The Armand Bayou Coastal Preserve is leased from the General Land Office by the Texas Parks and Wildlife Department. This arrangement limits construction adjacent to this preserve. The boundary of the preserve is the mean high water mark and the upper tidal limit of the Bayou, which is roughly 0.5 mile downstream of Genoa-Red Bluff Road.

FEMA Buyout

As a result of the 1998 Tropical Storm Francis, the City of Pasadena removed approximately 9 acres from the floodplain via a

PHOTO BY STEPHAN MYERS

FEMA buyout of 16 homes in the year 2000. Approximately another 14 acres was removed from the floodplain in 2002 through a joint buyout of 44 homes by Harris County and the City of Pasadena after the 2001 Tropical Storm Allison. These properties are required by FEMA to remain permanent open space and contain perpetual restrictions in each deed prohibiting them from being developed with any structure.

Detention Basins

Detention basins in the watershed range from small commercial systems owned by business owners to large systems serving hundreds of homes owned by community associations, as well as some very large regional systems that are owned by the City of Pasadena or Harris County Flood Control District. While some jurisdictions in the watershed have for many years required stormwater detention to mitigate development impacts, others have only more recently begun to do so. These basins can be designed for wet-bottom or dry-bottom detention. As wet-bottom basins, they may provide habitat for aquatic species. They may also be planted with native prairie vegetation. While detention basins are not protected land, the water storage volume they were designed to hold must be maintained. A detention basin could possibly be redeveloped if the water storage volume was mitigated to a nearby site.

Other

In addition, some other large parcels of land in the watershed are in public ownership, but not necessarily with legal/institutional protections. For instance, several hundred acres of undeveloped coastal prairie and flatwood forest areas lie within the Johnson Space Center, near Horsepen Bayou and Mud Lake. NASA currently leases the land from Rice University. No easement or formal conservation designation appears to be in place, but no plans to terminate the lease in the near future, or to further develop existing natural areas, are known.

Also, the University of Houston-Clear Lake (UHCL) campus straddles Horsepen Bayou, a tributary of Armand Bayou. The four-hundred-acre campus includes approximately 150 acres of riparian forest areas that are planned to remain wild in perpetuity. However, no easement protects this area. Additionally, a 37-acre tract at the intersection of Middlebrook Road and Space Center Boulevard has been donated to UHCL from NASA, and is to be used for environmental studies.

Possible Action Items Toward Plan Implementation for Habitat

To accomplish the Watershed Partnership's goal to "protect and restore valuable habitat areas through the watershed," Phase II action items may range from planning to restoration to acquisition. Some examples for the Phase II planning process could be:

1. Prioritize remaining open space for preservation.
2. Develop funding sources for placing critical habitats in the public domain.
3. Expand the riparian vegetation buffer along Armand Bayou and incorporate management of the buffer into flood control plans.

PHOTO BY ANN BRINLY

4. Work with private landowners of undeveloped land to develop land management plans that restore and enhance native prairies and riparian ecologies.

Water Quality

"Water quality" is a complex concept, comprised of physical, chemical, and biological components. Taken individually or collectively, these components are indicators of the environmental condition of a water body. The environmental condition of water bodies of the Armand Bayou Watershed can be described in different ways. For instance, some studies indicate that Armand Bayou has a diverse fish population indicative of "good" water quality. Conversely, Armand Bayou and its tributaries have experienced low concentrations of dissolved oxygen and fish kills, indicative of impaired water quality.

Since water quality data have only been collected for about thirty years, we cannot be certain if low dissolved oxygen levels occurred in the bayou prior to settlement, when the watershed was in its original condition. But as noted in the Introduction, major changes to the natural landscape have taken place resulting in impervious surfaces. These changes alter the natural hydrology and lessen the pollutant-filtering abilities of the soils and vegetation. The resulting increased storm water runoff, carrying pollutants such as fertilizers, pesticides and oil from our urban and suburban landscapes, can be detrimental to water quality.

In order to protect water quality, the Texas Commission on Environmental Quality (TCEQ) establishes water quality standards. The Texas Surface Water Quality Standards are designed to establish numerical and narrative goals for water quality and provide a basis for which TCEQ regulatory programs can implement and attain those goals. In Armand Bayou, standards are set to be protective of three categories of water use:

1. Aquatic life use – designed to protect plant and animal species that live in and around the water, such as standards for dissolved oxygen concentration;
2. Contact recreation - designed to lower the probability of human illness from swimming and other water sports involving direct contact with the water, such as standards for fecal coliform bacteria concentration; and
3. Fish consumption - designed

Sampling locations for Armand Bayou

to protect consumers from consuming fish or shellfish that may be contaminated by pollutants in the water, such as standards for mercury concentrations in fish tissue.

Various entities monitor water quality on a regular basis in the Armand Bayou Watershed, including the TCEQ, City of Houston Health and Human Services Department, and local Texas Watch citizen monitors. Each entity has its own set of monitoring stations, which are coordinated by the local Texas Clean Rivers Program partner agency, the Houston-Galveston Area Council. In addition to water quality monitoring, TCEQ assesses the data to compare actual water quality conditions to the established standards. The TCEQ assessment determines which water bodies are meeting the standards set for their use and which are not. Water bodies are considered impaired by the TCEQ if they do not meet applicable water quality standards or are threatened for one or more designated uses by one or more pollutants.

In fact, the tidal and above tidal portions of Armand Bayou are currently listed on the state's list of impaired water bodies, or the State of Texas Clean Water Act Section 303(d) List) because they did not meet TCEQ dissolved oxygen standards. Water quality samples evaluated in 1998 indicated that dissolved oxygen levels were periodically low, which could stress the fish community and other aquatic life.

In response to these data findings, the Texas Commission on Environmental Quality initiated a study in 1999 to determine the extent and severity of the low dissolved oxygen levels and the appropriateness of the water quality standard for aquatic life use. The initial analyses of the new data revealed that, while the dissolved oxygen concentrations were often low during hot weather, no indication was found that the aquatic life community was impaired. Nor did the study find oxygen-reducing pollutant(s) that would need to be controlled.

Because the 1999 study was inconclusive, a Total Maximum Daily Load, a detailed water quality restoration assessment, was not deemed appropriate to protect aquatic life in Armand Bayou. The TCEQ collects dissolved oxygen, nutrient, and chlorophyll data on a quarterly basis in Armand Bayou. These data will be used to help determine the causes of the low oxygen levels. Also, TCEQ has collected additional data on fish communities to help evaluate the effects of the Armand Bayou water quality regime.

Armand Bayou Water Quality Assessment

For the purposes of this watershed plan, data from the time period of 1998-2003 for eight key parameters – salinity, dissolved oxygen, chlorophyll-a, nutrients, bacteria, water clarity, sediment contaminants, and biological data – were chosen to assess the current state of water quality in Armand Bayou. Some of these parameters were compared to TCEQ water quality standards, although water quality can be less than optimal even when the water quality standards are attained. The standards were designed to cover a large range of water bodies, and represent a minimum for regulatory purposes. These standards may not be as protective of the watershed as desired by the Armand Bayou Watershed Partnership

To facilitate review, Armand Bayou and its tributaries were partitioned into seven distinct reaches. Four are on the mainstem: Mud Lake (the lower tidal reach downstream of the confluence with Horsepen Bayou), Middle Tidal (from the confluence with Horsepen Bayou to the confluence with Big Island Slough), Upper Tidal (near Oil Field Road), and Above Tidal (near Genoa-Red Bluff Road). The other three reaches represent major tributaries: Spring Gully, Big Island Slough, and Horsepen Bayou.

Descriptions and a summary of findings for each of the selected parameters are summarized below. A detailed discussion of the water quality assessment is located in Appendix F.

PHOTO BY JACK LEWIS, TEXAS DEPARTMENT OF TRANSPORTATION

Salinity

Salinity, a measure of the concentration of dissolved salts in the water, is important because living organisms, both plant and animal, are each adapted to live within a certain salinity range. As Armand Bayou is a tidally influenced water body, it will have generally decreasing concentrations of salt as one moves from the mouth of the bayou to the headwaters.

Salinity, which is usually reported in parts per thousand (ppt), ranges from less than 1 ppt in fresh water to 35 ppt in the salt water of the Gulf of Mexico. Since Armand Bayou is located in the Galveston Bay Estuary, a mixing zone for fresh and salt water, salinity naturally fluctuates with rainfall and runoff. Salinity is low during wet periods and higher during dry periods at the same location. The salinity of Armand Bayou and its tributaries ranged from 0.2 ppt to 20 ppt, typical of a low salinity estuarine system

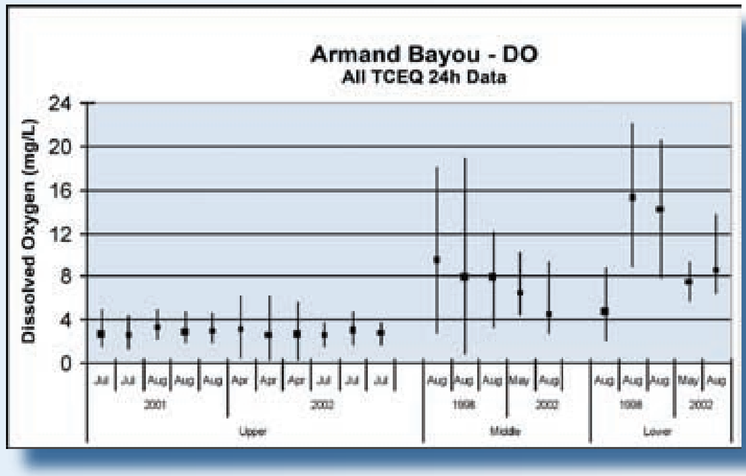
(Appendix F, Table 1). In addition to the three tidal segments of the mainstem, much of Horsepen Bayou and Big Island Slough are also affected by tides, so periodic higher salinity values are to be expected there.

Dissolved Oxygen

Dissolved oxygen is the concentration of oxygen in the water body as reported in milligrams per liter (mg/L). Dissolved oxygen is the traditional measure of aquatic health because aquatic organisms depend upon it; they will suffer if concentrations become too low. In the worst-case scenario, fish kills can result from very low concentrations (less than 2 mg/L). On the other hand, high concentrations of dissolved oxygen (greater than 10 mg/L) result from excess photosynthesis, which can also be detrimental to the water body (see Chlorophyll-a on page 28).

Dissolved oxygen concentration is dependent upon the temperature of the water, salinity, aeration from wind and water turbulence, the presence of oxygen-demanding substances and living organisms. Dissolved oxygen levels typically fluctuate in a daily cycle, with higher levels in the afternoon due to photosynthesis, and lowest levels in the early morning due to respiration (the use of oxygen by living organisms).

Dissolved oxygen levels in Armand Bayou may have been affected by accelerated subsidence (see Subsidence section). As the bayou deepened and widened, much of the fringing riparian forest was destroyed. Instead of being covered by a tree canopy, the bayou now has open water areas devoid of shade, which could result in higher temperatures and lower dissolved oxygen levels.



Dissolved oxygen data from Armand Bayou at Oil Field Road (Upper), Bay Area Boulevard (Middle) and Mud Lake (Lower). (Source: Previously unpublished TCEQ data)

The state water quality standard for dissolved oxygen in the tidal portion of Armand Bayou (from the confluence with Clear Lake to a point 0.5 miles downstream of Genoa-Red Bluff Road in Pasadena) is a minimum daily average of 4 mg/L. The above tidal portion (from a point 0.5 miles downstream of Genoa-Red Bluff Road in Pasadena to a point 2.5 miles upstream of Genoa-Red Bluff Road) requires a minimum daily average of 5 mg/L.

Dissolved oxygen can be measured either by instantaneous ("grab") samples or by continuous instrument monitoring over a 24-hour period. Overall, the grab samples indicated that dissolved oxygen was lowest in the Upper Tidal reach of Armand Bayou, averaging 4.4 mg/L at the surface and 3.5 mg/L below the surface. Dissolved oxygen levels in Mud Lake, Horsepen Bayou and the Middle Tidal reaches were generally high, with only a few surface readings that fell below 4 mg/L (Appendix F, Table 2). It is important to note that some of the grab samples utilized in this assessment were taken in the afternoon, after a day of photosynthesis, and, therefore, may not reveal the actual minimum dissolved oxygen in the water body.

To better determine the minimum dissolved oxygen levels experienced by a water body, instruments were deployed that measured the oxygen levels every 15 minutes throughout the day and night. The graph illustrates the dissolved oxygen range measured in different parts of Armand Bayou (the Upper, Middle, and Lower Tidal reaches) over several distinct 24-hour periods. Each month, the measurement was taken at the same location for each reach of the bayou. Each vertical line represents the dissolved oxygen range from one 24-hour period and the square indicates the average dissolved oxygen for that 24-hour period. This graph shows that the Upper Tidal reach experienced very low dissolved levels frequently, while the Middle and Lower Tidal reaches experienced both very high and very low dissolved oxygen values in a single day. Values above 10 mg/L indicate the presence of an algal bloom, while values below 4 mg/L do not meet the minimum water quality standard. While the grab samples have the disadvantage that unrepresentative concentrations may result if samples are not taken in the morning, the pattern of lowest dissolved oxygen in the Upper Tidal reach was consistent in both types of samples.

Dissolved oxygen studies are currently being undertaken by the Texas Commission on Environmental Quality in order to address the need for a Total Maximum Daily Load.

Chlorophyll-a

Chlorophyll-a is a measure of a photosynthetic pigment in green plants in micrograms/liter (µg/L), and is an indicator of the algal population (phytoplankton). Phytoplankton are microscopic algae that drift in the water, harnessing the energy of the sun and making it available to living organisms. Through this mechanism, they form the base of one of two types of food webs in the Galveston Bay system. Additionally, dissolved oxygen is produced as a byproduct of algal photosynthesis. While phytoplankton are beneficial through this energy capture and oxygen production, excessive concentrations of phytoplankton, or algal blooms, can become detrimental to a water body. These blooms, which require high amounts of dissolved oxygen when they respire at night or when decomposing following death, are usually caused by excess nutrients in the water. Thus, chlorophyll-a is an important measure of bayou health.

In Armand Bayou, average chlorophyll-a values were highest in the Mud Lake, Middle Tidal, and Horsepen Bayou reaches, where the dissolved oxygen levels were also very high (Appendix F, Table 3). Chlorophyll values above 20 µg/L are generally considered detrimental; the average values in these three segments exceed that threshold, sometimes by a large margin.

Nutrients

Nutrients are necessary for the growth of plants, including phytoplankton. Low concentrations of nutrients can reduce plant growth and therefore impede the production of food for dependent living organisms, while excess concentrations can cause algal blooms. Nutrient concentrations are sometimes measured to determine water quality as it relates to non-point source (storm water runoff) pollution and wastewater treatment. Nutrient parameters measured in Armand Bayou and its tributaries included ammonia and total phosphorus, reported in mg/L. Another important parameter, nitrate-nitrite, was not included in this assessment because a complete data set for Armand Bayou was not available.

Both ammonia and total phosphorus values were high in Horsepen Bayou while only phosphorus was elevated in Mud Lake and Middle Tidal reaches (Appendix F, Table 4). These are the same areas that exhibit high chlorophyll-a concentrations and high dissolved oxygen.

Fecal Coliform Bacteria

Fecal coliform bacteria are present in the intestines of animals. They are an indicator of the presence of human or animal waste in the water and thus are an important public safety measurement. Fecal coliforms themselves do not typically cause illness in humans, but their presence indicates that other disease-causing microbes could be present. A screening level for individual samples has been set at a maximum 400 colonies (cfu)/100ml to be protective of swimmers. After a heavy rain event, most water bodies will have high fecal coliform levels. If the screening level is exceeded by more than 25% of the individual samples, the water body will be listed as impaired by the TCEQ.

Based upon the screening level, fecal coliform bacteria counts were high in about 20% of the samples collected in Armand Bayou and its tributaries (Appendix F, Table 5). No obvious differences among the reaches were found.

Water Clarity (Turbidity)

Water clarity is a measure of the amount of sunlight that can penetrate the water column. Clarity is decreased by the presence of suspended and dissolved materials, which may be from living matter such as phytoplankton or from non-living matter such as sediment. Since submerged plants need sunlight for growth, this is an important parameter. Waters that have low clarity are said to be turbid. The degree of turbidity can be measured by the use of a Secchi disk, a black and white disk that is lowered into the water to the point just above where the disk is no longer visible. That point, measured in meters, is referred to as the Secchi depth.

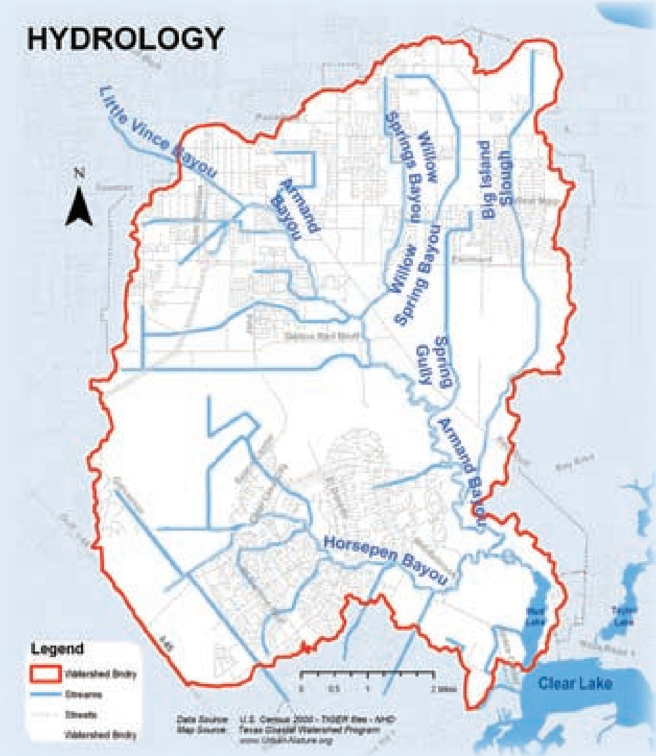
The data indicate that water clarity averaged the lowest in the Mud Lake and Middle Tidal reaches (Appendix F, Table 6). Local waters are noted for their relatively high turbidity. However, it is important to track turbidity, since man-made inputs from construction sites, urban development, and other land use changes may artificially decrease water clarity.

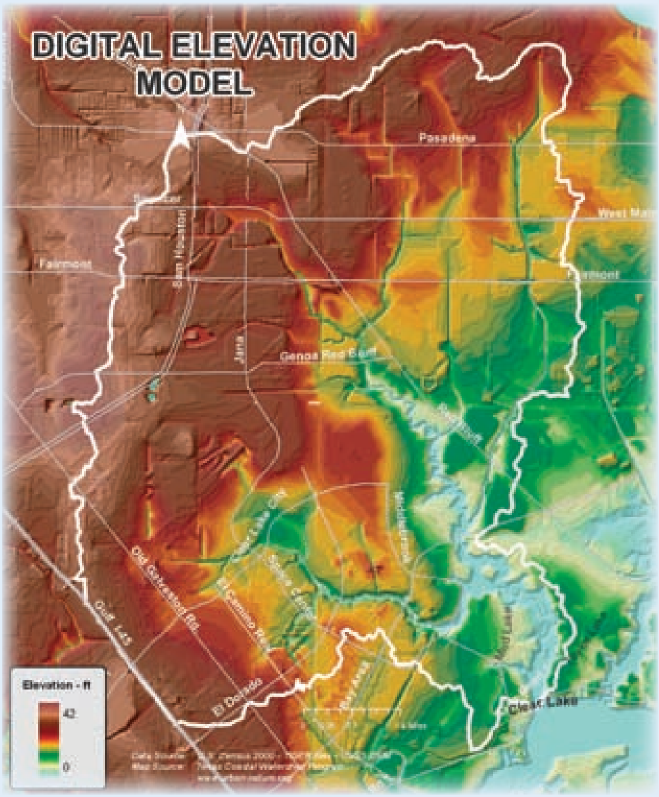
Sediment Contaminants

Contaminants in sediments may cause adverse effects to living organisms. Many pollutants are transported into the waters of the Galveston Bay area attached to sediment particles. These compounds may remain in the sediments for many years and can be passed up the food chain to humans. Contaminants in the sediments may include metals or organic compounds that originate from natural or man-made sources. Some metals of concern and their potential sources include:

- arsenic (from fossil fuel combustion and industrial discharges);
- barium (from oil and gas drilling muds, bricks, tiles, and rubber);
- cadmium (from corrosion of alloys and plated surfaces, electroplating wastes and industrial charges);
- chromium (from corrosion of metal plated surfaces, electroplating wastes, and industrial discharges);
- copper (from corrosion of copper plumbing, anti-fouling paints, and electroplating wastes);
- lead (from leaded gasoline, batteries, and exterior paints and stains);
- mercury (from natural erosion and industrial discharges);
- nickel (from nickel plating and batteries); and

PHOTO BY STEPHAN MYERS





- zinc (from tires, galvanized metal, and exterior paints and stains).

Sediment was sampled for metals twice in 2002 by the TCEQ. In those samples, no metal concentrations exceeded screening levels that are associated with adverse effects in living organisms. See Appendix F for further discussion.

Biological Data

The study of water quality in the Armand Bayou watershed would be incomplete without an assessment of its dependent living organisms. The Texas Commission on Environmental Quality collected data on biological parameters from three sites in 2002. The data are currently being evaluated by the agency, along with data collected by Parsons, Inc. for its "Report for Water Quality and Biological Characterization of Armand Bayou, Houston, Texas, (May, 2000)."

Fish kills are sudden die-offs of significant numbers of fish and they indicate that an aquatic environment has become unsuitable. Fish kills may be caused by low dissolved oxygen, spills of toxic materials, or extreme temperatures. Records show seven major fish kills in the Armand Bayou watershed since 1971; most located in the tributaries (Appendix F, Table 7). Four were attributed to low dissolved oxygen. The fish kills were short in duration.

Flooding and the Water Quality Connection

In addition to damage to the built environment, flooding brings a large volume of pollutants from the Armand Bayou Watershed to its water bodies. In the built environment, contaminants such as excess sediment from construction areas and eroding land, fertilizers, pesticides, oil and grease and floatable trash are transported to Armand Bayou and its tributaries. While the concentration of these contaminants may be low due to the large volume of water transporting them, the actual loading (the concentration multiplied by the runoff volume) of these contaminants can be detrimental. In addition, the biological component of water quality can be harmed as abnormal high stream flows, resulting from increased impervious surfaces and storm sewer infrastructure, scour the bayous and streams of natural habitat.

Possible Action Items Toward Plan Implementation for Water Quality

To accomplish the Watershed Partnership's goal to "enhance water quality to minimize fish kills, maintain aquatic diversity, and provide safe contract recreation opportunities," Phase II action items may range from increased monitoring to improved management of runoff pollution. Some examples for the Phase II planning process could be:

1. Utilize automated dissolve oxygen sampling to better capture potential impacts to the aquatic life community.
2. Incorporate water quality features in detention basins.
3. Plant trees along streams to provide stream cover, which would reduce water temperatures and improve dissolved oxygen values.

Flooding and Stormwater Management

Flooding is a natural occurrence for any river or bayou. The Armand Bayou watershed is even more prone to flooding because of several conditions that make stormwater management a challenge. The Texas Gulf Coast is a semi-tropical environment capable of receiving substantial amounts of rain in a given event. The average annual amount of rainfall for the Armand Bayou watershed is approximately 48 inches. Occasional tropical storms and hurricanes cause heavy accumulations (several inches per hour) in a very short time. The topography of the area is extremely flat with a slope of less than one foot per mile. This, coupled with heavy rainfall, results in slow-moving runoff. Additionally, hurricane force winds are often accompanied by storm surges that cause the bayou to flow backwards as the storm comes ashore. The proximity of the watershed to the Gulf of Mexico and Galveston Bay, and its low overall elevation, means that ocean tides also affect the area. Furthermore, the generally clayey soils have relatively slow infiltration rates, further exacerbating the flooding potential.

Pre-settlement runoff was significantly different than it is today. With the large amount of flat lands in the watershed, the wetland depressions, and the stream associated vegetation, seasonal and peak rainfall patterns of Armand Bayou would have been very different. Less water ran off, and ran off over a longer period of time, after each storm event.

In an effort to drain large flat areas of the watershed, early settlers constructed ditches. The more modern human influences of development in the watershed have resulted in the creation of more hard surfaces. As rain falls on these developed sites, the volume that runs off is increased. Rain also flows across these smooth surfaces faster, creating expedited rates of runoff. In the development process, these two effects must be mitigated in order to maintain upstream and downstream flow conditions.

The region as a whole has also experienced significant land subsidence due to ground water withdrawal. The upper portion of the watershed has subsided more than the lower portion, which has resulted in a flattening of the stream gradient and, therefore, slower runoff.

Stream Infrastructure

Stream Facts

Basic stream facts — including such information as stream segment length, sub-basin area, approximate number of outfalls into each segment, and size and capacity of detention basins — are shown on the spreadsheet provided as part of Appendix H to this report.

Flows

The point of discharge of the Armand Bayou Watershed into Clear Lake is at NASA Parkway, approximately 3.4 miles upstream from Galveston Bay. According to the Clear Creek Regional Flood Control Study Report, the maximum allowable discharge rate of Armand Bayou, to prevent downstream flooding in Clear Lake, is 24,827 cubic feet per second for the one-percent event.[22] The City of Houston Wastewater Treatment Plant located adjacent to Horsepen Bayou contributes a maximum allowable discharge of 47.9 cubic feet per second, with an average discharge of 15.5 cubic feet per second.

Pre-settlement water flows would have been substantially different than those seen today. Because many natural surfaces have been paved over, much of the rainfall runs directly into the bayous, without infiltrating into the soil as much of it would have done prior to development. The water that was stored in the natural wetlands and that seeped into the soil would have provided a more constant "base" flow in Armand Bayou and its tributaries than seen today.

A common misconception is that the very clayey soils that are so common in this watershed differ very little from hard surfaces such as asphalt or concrete. While clayey soils do take on much less water than sandy soils (particularly in the winter), the clayey prairie soils in this watershed in their native state were able to absorb much more water than an impervious surface such as concrete, which absorbs no water at all. The naturally high amount of organic matter in the native prairie maintained good structure in the soil, which allowed a relatively high amount of water to seep into the soil.

The paving over of natural surfaces greatly aggravated flooding in the watershed. Increasing the runoff rapidly exceeded the receiving capacity of the bayou channels. It is important to remember, however, that flooding was a natural and frequent occurrence in this watershed. Prior to settlement, very few natural streams were present in the watershed, so that once the capacity of the vegetated wetlands and the infiltration capacity of the soil were exceeded (a not infrequent occurrence in the winter months when the soils swell shut), water would collect and stand until it could slowly run off. Paving has affected mainly the smaller storms. A large storm, such as Allison, would have caused flooding regardless of development in the watershed.

Types of Flooding

Three types of flooding occur in the Armand Bayou watershed: stream flooding (overbank), outside the floodplain flooding, and coastal flooding (storm surge).

Stream Flooding

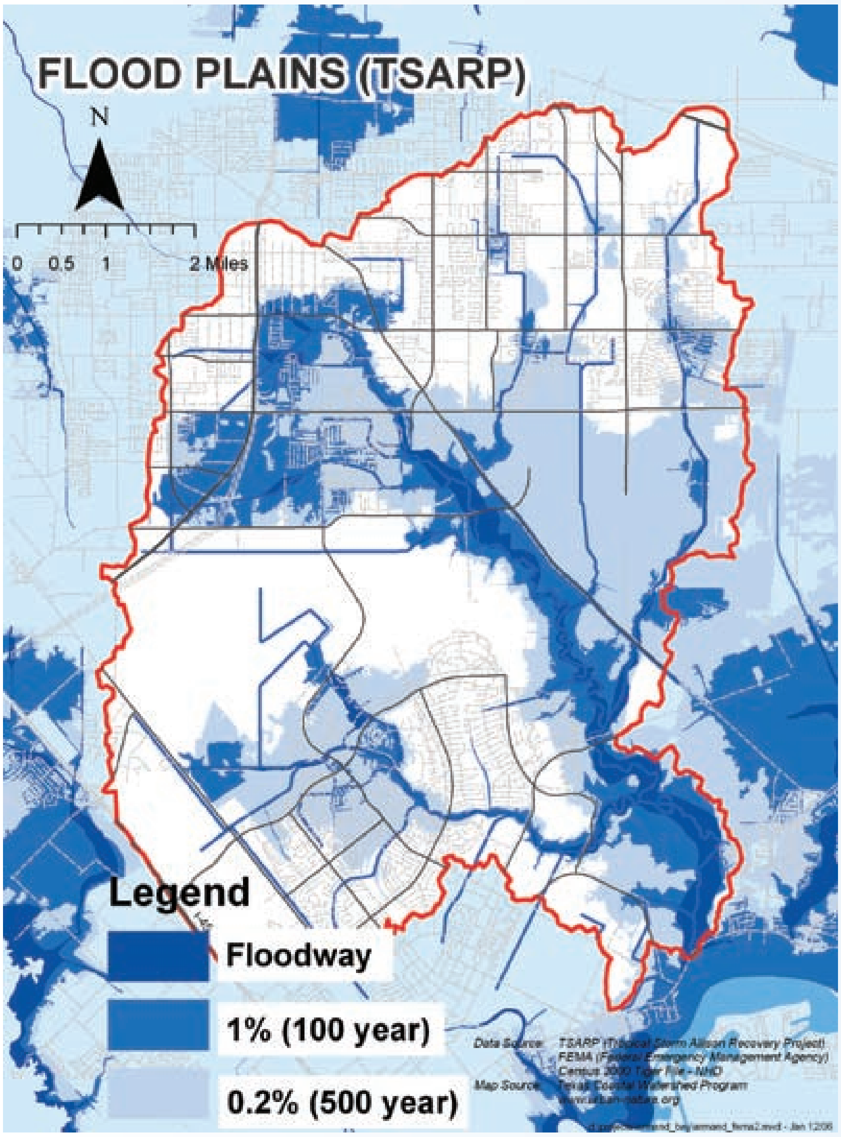
Shallow floodplains exist throughout much of the county and incorporate thousands of residences and businesses. Flooding begins when the channel capacity is exceeded and usually lasts for hours rather than days.

Outside the Floodplain Flooding

Another flooding scenario is caused by ponding and overland flow, and can occur almost anywhere. When intense local rainfall exceeds storm sewer or roadside ditch capacity, the water can pond in the streets enough to flood residences that are not necessarily near a creek or bayou.

The water will seek a path to the channel by flowing overland

[22] The "one-percent" event is the rainfall amount that has a one-in-100 chance of occurring in any given year. This has also been termed the "100-year" event in the past, but that term implies that the rainfall event should only occur once in 100 years, which is a less accurate way of conveying the chances.



(sheet flow). When residences and other structures are in that path, additional flooding can occur. This type of flooding is not identified on the Flood Insurance Rate Maps.

Coastal Flooding

Coastal flooding occurs when unusually high tides or hurricane surges inundate low-lying structures. Ground subsidence can result in more frequent and severe coastal flooding.

Subsidence and Flooding

When subsidence causes an increase in the stream gradient (the slope), flooding generally decreases. When the stream gradient decreases, flooding generally increases. The subsidence from 1906 to 1978 caused the stream gradient to decrease along Armand Bayou and most of its tributaries, and, therefore, created more flooding.

Tide and storm surge heights are not affected by subsidence. However, in tidal areas in the watershed, an increase in the amount of terrain inundated by tidal and storm surges is directly correlated to subsidence: The land is lower, but the tide and storm surge heights are unchanged; hence, these natural occurrences inundate more land.

Subsidence is not reversible, but can be controlled, as illustrated by the actions of the Harris-Galveston Coastal Subsidence District, created in 1975. Since then, implementation of the Subsidence District's plan has halted the accelerated subsidence in the watershed.

Changing Floodplains

Flooding is a natural occurrence, but flooding problems are exacerbated by urbanization. Urbanization has resulted in increased runoff, which has overwhelmed natural channel capacities. The first large-scale development began about forty-five years ago, and development has proceeded rapidly since that time. With the creation of the regulatory floodplain around 1970, development approvals within the floodplain have generally ceased. Certain developments built outside the floodplain prior to 1970 exist in what is now the current floodplain. Many of those structures experience repetitive flooding.

New and better analytical tools have been developed, which have improved the mapping of floodplains. New floodplain maps, based on land elevations determined using LIDAR (LIght Detection And Ranging), are becoming available from the Harris County Flood Control District (See www.tsarp.org).

Areas Experiencing Repetitive Flood Losses

In response to the skyrocketing cost of these insurance claims for the National Flood Insurance Program, FEMA began offering funds through the Hazard Mitigation Grant Program to remove those homes that have the greatest likelihood of flooding multiple times. From 1998 to 2003, more than 60 homes in Pasadena were removed from the floodplain in the upper watershed, and that land has been protected from future development.

As of 2003, the areas eligible for buyout using FEMA hazard mitigation funds have been Cresthaven Estates, and Bliss Meadows, south of Spencer Highway. The portion of Armand Bayou near Spencer Highway at Denkman and Trebor Streets has also experienced repetitive flooding losses. Approximately 80 homes in the Spencer Village subdivision, the Brandywood apartments and the about 6 nearby businesses have suffered repeated flooding. Homes in the Country Briar subdivision (located along B115-00-00 [see Appendix I]) have also suffered repetitive flooding.

Voluntary Buyout Status

Voluntary buyout of flood-damaged homes has been a major focus in the Armand Bayou watershed. With money available from the Federal Emergency Management Agency (FEMA), about 60 homes in the upper portion of the watershed have already been purchased (and demolished—and removed from future development) as part of recovery efforts after significant flooding events that occurred in 1998 and during Tropical Storm Allison in 2001. More buyouts may be possible if additional funds become available. Buyouts using FEMA funding are totally voluntary on the part of the seller. HCFCD may also consider voluntary buyout of other homes that are deep in the floodplain and cannot be removed from harm's way as part of the Flood Damage Reduction Plan. This Plan aims to lessen damages caused by flooding and may include a combination of structural and nonstructural elements.

Flood Insurance Study

FEMA Flood Insurance Rate Maps (FIRMs) are maps that show areas subject to flooding from a primary flooding source – typically streams – and show floodplains based on a 1% chance of flooding (sometimes 2% as well) in any given year. The FIRMs for Harris County, including Armand Bayou, were first produced by FEMA in May 1970. Subsequent revisions occurred as more reliable data became available. Most of the maps have been updated to November 6, 1996, and remain valid to date. Revisions are underway.

The FIRMs and the associated profiles reveal that the base flood elevation (BFE) downstream of Bay Area Boulevard is less than 12 feet msl for a storm surge type of event. Ground elevations in this area average 15 feet, but range from 5 to 20 feet msl. Upstream of Bay Area Boulevard, storm surge effects dissipate. The BFE downstream of Genoa-Red Bluff Road is 20 feet msl. Near Beltway 8, where ground elevations are generally 35-40 feet, the BFE reaches 30 feet msl.

The watershed's 1% riverine floodplain covers roughly 4,300 acres, or just less than seven square miles (as mapped as of December 1991). Hurricane surges in the lower reaches increase the amount of land in the 1% floodplain. During the 1% and more frequent events, the main stem and its tributaries are out of their banks. The main stem floodplain delineated on the FIRMs average more than 2,000 feet wide for the 1% storm. Segments of Armand Bayou tributaries contain the 1% event.

Detention

The concept of stormwater detention as an urban stormwater management tool is widely used throughout the Texas Gulf Coast. Detention is designed to alleviate expedited and increased runoff by collecting the rain that falls on a given site, directing it into an oversized storm sewer or basin, and detaining it from discharging into the stream or public storm sewer system until the peak flow of the stream or system has subsided. It then releases the stormwater through a small outflow pipe that is placed at an elevation below peak flow. Although detention facilities in upper reaches of a watershed have been found to reduce flood levels, detention in the lower reaches of a watershed is generally unnecessary because the objective is to flush the water out before the headwaters flow downstream.

Detention has been used to varying degrees by communities in the watershed. Detention gained popularity as a regulatory mechanism around 1980, but not all communities chose to require detention at that time. Most communities now require detention for large residential developments, and many require detention in some form for even small commercial development. Numerous private, onsite detention facilities ranging in size from less than one acre to more than 25 acres are scattered throughout the watershed.

In addition to requiring detention to offset impacts of a particular development, some communities have begun to provide large regional facilities on their own and/or in partnership with HCFCD to offset past development impacts. These facilities range in size from 35 acres to over 135 acres on upper Horsepen Bayou, Ellington Air Field, upper Armand Bayou, and near the actively developing Beltway 8 / Fairmont Parkway area.

Possible Action Items Toward Plan Implementation for Flooding and Stormwater Management

To accomplish the Watershed Partnership's goal to "reduce the impact of flooding on homes and business, using the watershed's natural ability to absorb floodwaters wherever possible," Phase II action items may range from continued use of voluntary buyouts to changing the amount of impervious cover in the watershed. Some examples for the Phase II planning process could be:

1. Explore all avenues for voluntary buyouts of repetitive flood loss properties.
2. Develop pilot projects on effective best management practices to reduce surface runoff from residential properties.
3. Develop ordinances to reward strategies that reduce runoff from residential and/or commercial properties.

Demographics

Who lives in the watershed? People are just as much a part of the watershed as the land, plants, and animals we have described in previous sections, and are part of what makes each watershed unique.

Examination of information available from the 2000 census reveals some interesting patterns. As shown in the first illustration, most of the development in the watershed did not begin until the 1960's, with most of the building occurring in the 1980s and 90s. The newest development is occurring in the central part of the watershed—northern Clear Lake and southeast Pasadena. Income is not evenly disturbed throughout the watershed—the wealthiest citizens live in Clear Lake and southeast Pasadena but a pocket of relative affluence is also found in Deer Park (Appendix C). The home ownership or tenure map (Appendix C) mirrors somewhat the income map but shows where the most stable populations occur—again: Deer Park, Clear Lake, and southeastern Pasadena.

The Travel Time to Work map (Appendix C) reveals how many people work in or near the watershed –time to work is smaller the closer your work is. The southern fringe of the watershed has a lot of people who work at NASA, and the Deer Park area has a significant number that work near the Houston Ship Channel. By and large, though, most people work at some distance to the watershed.

Demographics have been changing in the watershed. One demographic map in Appendix C shows the relative proportion of foreign-born residents in the watershed. Others show that Latinos and Asians are the dominant immigrant groups, with Asian populations concentrating in the Clear Lake area and Latinos in the upper part of the watershed. The highest concentrations of African Americans are found in the southwest corner of the watershed (Webster) and in the southernmost sector of the watershed.

Public Education and Outreach

Improved stewardship and involvement by the general populace is crucial to the successful restoration and preservation of Armand Bayou. Stewardship and involvement build ownership within the community and ultimately reduce management costs. Increased involvement and better stewardship may be developed through a greater awareness and understanding of the economic and environmental value the bayou possesses.

A coordinated outreach and public education campaign is necessary to enhance understanding, change attitudes, and stimulate action of people within the watershed. With knowledge, people can make informed decisions at home in regards to conservation landscaping, vehicle maintenance, disposal of household hazardous materials, and others. They are equipped to carry out individual and community-wide projects, such as conservation landscapes, trash pick-ups, recycling, water gardens, community vegetable gardens, and use of multi-purpose open space parks. As people learn more, they are more likely to engage in the decision making process, affecting policy and management decisions.

Awareness and Stewardship

Almost every visitor to the Armand Bayou Nature Center (Nature Center) understands the beauty and value of Armand Bayou. The water and its riparian corridor seem an intact, undamaged area; visitors are often unaware of the signs of subsidence and other human disturbance. They support the protection of this and similar natural areas. But the same patrons may not understand that they live in the Armand Bayou watershed, and that what they put on their lawns or throw on ditches or streets ends up in the Bayou itself.

In the Houston area, watersheds as a system are poorly understood. This is one of the main challenges facing the Armand Bayou watershed: how to create a sense of identity and community amongst the residents of the watershed, and an understanding of how watersheds work, so that they value the Bayou and its watershed and become effective stewards.

Current Outreach Efforts

The greater Houston region has benefited from years of water quality outreach, by various organizations ranging from the Texas Commission of Environmental Quality to the regional Houston-Galveston Area Council to more localized efforts, such as by the Nature Center. (See Appendices I and J.) While not always coordinated, the message does in fact seem to be catching on. Citizens are aware that water quality affects them as well as the environment, and have for the most part eliminated obviously detrimental actions like dumping used car oil into the storm drain. However, as mentioned above, they do not always make the connection between the storm drain in their street and the bayou ecosystem.

Generally speaking these outreach efforts can be categorized as one (or more) of the following:

Promotional Materials. These publications have been printed or are online and are often readily available; videos that can be borrowed or otherwise obtained for viewing. These are valuable to supplement presentations and to hand out at fairs and other outreach events with mass attendance. The material

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is standardized, and therefore the message is presented equally to all audiences. Printed materials help reinforce a message that may be lost, as they can be read and re-read at leisure. Because they have already been produced, these promotional items can usually be obtained free of charge, even in large quantities.

Workshop and Classroom Activities. Many organizations offer workshops to provide a hands-on experience. These range from creating a wildlife-friendly habitat on school grounds to wading knee-deep into the bayou to collect and examine "bugs" (macroinvertebrates) to locally based ecology courses like Master Naturalists. In some cases, the participants enroll and attend at a specific organization's facility (as in the case of the Nature Center's EcoDays); but in other cases, educators go to schools and teach students in their classrooms as part of their school curriculum. In addition, the activities can be varied depending on the educator and the audience, for a more individualized lesson.

Public Participation Opportunities. For those seeking a greater level of involvement, numerous opportunities for direct public participation exist. Storm drain marking, regular water quality monitoring, local recycling programs, clean-up days, and other activities are organized by the municipalities and organizations in the area. These are often highly staff- or volunteer-intensive, yet regularly are reported to have the greatest impact upon participants. Such opportunities also have the ability to provide immediate, direct, and quantifiable impact upon the environment.

Much of the outreach available in the Armand Bayou area is listed in the Appendices I and J.

Possible Action Items Toward Plan Implementation for Public Outreach and Education

To accomplish the Watershed Partnership's goal to "improve awareness and understanding" and to "increase stewardship of Armand Bayou and its tributaries," Phase II action items may range from continued developing a coordinated outreach plan to promoting Armand outreach through new venues. Some examples for the Phase II planning process could be:

1. Develop and widely disseminate the results of the Phase I and Phase II plans.
2. Review regional, state, and national polls, and conduct local polling to determine the most effective messages to accomplish the Watershed Partnership's mission.
3. Develop key themes to serve as core messages to be incorporated in promotional materials and classroom/ workshop activities by jurisdictions and organizations in the watershed.

Parks

A portion of the Armand Bayou Watershed Partnership Mission Statement is to improve the quality of life of the residents in the community. Parks and their availability play a role in the quality of life for a community. The municipalities in the Armand Bayou watershed are the City of Houston, the City of Pasadena, the City of La Porte, the City of Deer Park, and the City of Taylor Lake Village, all within Harris County Precinct Two. The City of Houston and the City of Pasadena comprise the greatest amount of land in the watershed, with 14,079 acres and 12,129 acres, respectively. Harris County, the City of Houston, the City of Pasadena, and the City of La Porte have adopted park master plans, which provide park system inventories and evaluation of the status of the park systems in relation to identified needs, goals, and objectives for parks in their respective areas.

The Greater Houston metropolitan area, like much of the nation, is growing. All municipalities in the watershed have acknowledged this growth in their master plans, as well as recognized the importance of expanding parks and open space

to meet the needs of a growing population. For many years, to find the suitable amount of parkland per population, municipalities relied on standards of the National Recreation and Park Association (NRPA). While those standards are no longer in place, it is important to estimate the amount of park acreage needed for a population. Local governments have used NRPA guidelines, as they relate to the size of parks, to evaluate the adequacy of their park systems and develop target goals, in the ranges listed in Table 1. However, each municipality's definition varies in acreage size, so classification of a park type is dependent upon the classification system of the municipality within which the park lies.

Table 1. Traditional Park Guidelines

Park Type	Service Distance	Desired Size	Desired Acreage per 1,000 people
Neighborhood	1/2 -1 mile	1 to 10 acres	1.25 - 2.5
Community and Linear	1 -3 mile	5 to 50 acres	5.0 - 8.0
Regional	Up to 5 miles	50 to 200+ acres	15 - 20

Table 2. Harris County Precinct Two Amenity Priorities

Rank	Priority
1	Land acquisition/ park expansion
2	Trails (natural and hard surface)
3	Nature/ Conservation areas
4	Soccer Fields
5	Football Fields
6	Skate park
7	Trees/ landscaping
8	Art, monuments, sculpture, etc.
9	Playgrounds

Harris County

The Armand Bayou watershed is found inside Precinct Two, which is in the eastern section of Harris County. *The Harris County Master Plan for Parks, Recreation, and Open Space* (Harris County Park Master Plan) was adopted in May 2001. Harris County has eight parks within the watershed, which include one neighborhood park, three community parks, one regional park, one linear park, one special use park, and one undeveloped park. Five of the parks can be found inside city limits, with three in unincorporated sections of the county.

General Goal and Objectives

The general goal of the Harris County Park Master Plan is to serve all recreational needs by promoting and developing parks in Harris County, while remaining fiscally responsible and mindful of parks in incorporated municipalities. The general objectives are to follow park standards – those can be found in the Harris County Park Master Plan - and improve park safety and accessibility. The County's goal towards the natural environment is to " continually identify, protect, and preserve quality natural open spaces for unstructured recreational activities, inherent aesthetic value and protection of valuable ecosystems," by working with surrounding governments and organizations, limiting development in sensitive areas, and returning parkland to their natural habitat.

Needs

In order for Harris County to meet its acreage goals for parks, it would need to acquire large tracts of land and develop them as parks or open spaces. Along with meeting the parkland acreage goal for the existing population, the acquisition of land in the county is important in order to keep up with the population growth, especially in areas that are not within incorporated cities. Precinct Two, as well as the other three precincts of Harris County, has identified desired recreational amenities. Table 2 gives an abbreviated ranking of park amenities for Precinct Two, as identified by Precinct Two park staff.

Houston

The City of Houston Parks and Recreation Master Plan (Houston Parks Master Plan) was adopted in October 2001. Houston has 3 parks inside the watershed, 1 neighborhood park, 1 regional park, and 1 linear park, with a total of 307 parks throughout the city. Many of the city goals, objectives, and needs may not apply or affect the portion of the city inside the Armand Bayou watershed.

General Goals and Objectives

Houston's parks goals and objectives can be found in full in the Houston Parks Master Plan, October 2001. The master plan has identified goals to provide all park types, recreational facilities, and activities to all citizens, while managing to encourage proper use. One goal speaks to a related goal of the Armand Bayou Watershed Partnership, that is, to use the park system to protect environmentally significant areas within the city for the public and for education. The objectives for all of these goals includes such things as: utilizing alternative sources of land, providing facilities to underserved areas, designing new durable parks, redeveloping existing parks, making use of partnerships, and expanding linear park system along bayous, rivers, and streams.

Needs

Park needs in Houston were identified for seven sectors of the city. The Southeast sector encompasses the area around I-45 between 610 Loop and the City of Webster, and a portion of the Armand Bayou watershed lies within this section. Sections of the Needs Assessment for the Houston Parks Master Plan have been left out of this discussion if they did not apply to the Armand Bayou watershed.

Three methodologies, or criteria, were used to identify the needs for parks: standard-based, demand-based, and resource-based. Defining needs through standard-based criteria involves analyzing state and national standards and a comparison across cities. A demand-based criterion takes into account public input. Resource-based criteria recognize unique resources, historical and natural, that should be protected in the park system.

To meet the goals set, the city would need to acquire eight new sites to abide by park standards and to match the community's demand, and this would also provide an opportunity for joint ventures. An expansion of two existing parks would improve park access and visibility, which would also relieve overuse. To improve park development, the city needs to rehabilitate and restore all existing parks, based on the current condition of existing parks, the popularity of the Parks to Standard Program (PTS), and community demand. Improvement and/or development of two vacant or undeveloped park sites is needed because of existing urbanized areas with inadequate parkland. To resolve conflicts with other sport activities the city needs to build two more soccer fields at existing and new parks and relocate tournament fields out of neighborhood parks. Also, constructing a new recreation center would serve communities and regions currently without centers. Acquiring and constructing seven new facilities would eliminate substandard facilities and reduce travel time by personnel.

Pasadena

The current *City of Pasadena Parks, Recreation, and Open Space Master Plan* (Pasadena Park Master Plan) was adopted in 1998. There are 7 parks in the Armand Bayou watershed that are owned and managed by the City of Pasadena, 4 pocket parks, 2 neighborhood parks, and 1 undeveloped park.

General Goals and Objectives

The general goal of the Pasadena Park Master Plan is to develop and enhance a balanced network of facilities that will serve the recreational needs of all the citizens. The general objectives are to adopt the standards and guidelines that are set in the park classification section of the Pasadena Park Master Plan and improve all parks by ensuring their access, safety, and maintenance standards. Environmentally, a goal of the Pasadena Park Master Plan is to protect and acquire open spaces for "unstructured" recreation, "aesthetic value, and protection of valuable ecosystems."

Needs

The identification of needs for the parks in the City of Pasadena was based on three methodologies. The standard-based methodology placed all parks into categories similar to those used by NRPA for assessment. The second method was demand-based and involved input, in various forms, from the public. The third method, resource-based, concerned analyzing unique resources in the city that would enrich the experience of users.

From these three approaches, the City has found that no more pocket, or mini, parks are needed; instead there is a need for neighborhood, community, and regional parks. A greenway, or trail, system is also needed to link the city park system together. Both of these needs require land acquisition or re-development of existing parks to more adequately meet the needs of the citizens. The city also needs to acquire more facilities, such as aquatic centers, playgrounds, recreation centers, RV parks, and picnic areas. Additionally, the citizens of Pasadena expressed a need for citywide beautification and an increase in natural areas.

La Porte

The La Porte Park Master Plan was adopted in 2001. The City of La Porte has 8 parks inside the watershed, which include 2 neighborhood parks, 1 community park, 3 regional parks, and 2 undeveloped parks. Like the City of Houston, many of the goals, objectives, and needs were written after assessing the entire city, so some of them may not apply or affect the portion of La Porte inside the Armand Bayou watershed.

General Goals and Objectives

The La Porte Park Master Plan identified seven goals, all followed by ensuing objectives for achieving the goals. One goal, however, stands out because of its compatibility with the goals of the Armand Bayou Watershed Partnership. The goal is to "preserve and protect unique natural open spaces and important habitat areas for threatened and endangered species of plants and wildlife." The objectives for this goal include such things as: improving the environmental quality of Galveston Bay, acquiring new land and maintaining existing lands, practicing sound flood management, and promoting environmental education.

Needs

The La Porte Park Master Plan has broken the park needs into two categories; facility needs, based on usage and standards, and citizen-expressed desires. The highest priorities based on facility standards are the addition of trails in the city, more nature viewing areas, more pavilions, more soccer fields, more baseball complexes, and more practice areas. The citizens of La Porte recognized some of the same needs as set by facility standards, but also acknowledged additional needs. High priority needs based on citizen feedback are more playground equipment, more picnic facilities, more trails, more natural habitats, more pavilions, and more senior centers. The Park and Recreation Department has also recognized a need to improve existing parks, playground safety, update over-used parks, and acquire more parklands.

Possible Action Items Toward Plan Implementation for Parks in the Watershed

To accomplish the Watershed Partnership's mission of "improving the quality of life in our community," Phase II action items may range from increasing water access to expanding park acreage. Some examples for the Phase II planning process could be:

1. Identify points of possible water access to the Armand Bayou and its tributaries.
2. Acquire new lands for new and existing parks in the watershed.
3. Identify areas of possible connectivity between parks and between the Armand Bayou and parks.

Institutional Framework

Very few laws exist that directly protect and regulate usage of wetlands and natural areas. However, several federal and state laws provide some degree of protection for natural resources. Pertinent laws and implementing agencies are described in their respective sections below.

The Phase II Plan will build on the Phase I Plan to address implementation of the Armand Bayou Watershed Partnership's (Watershed Partnership) goals toward accomplishing its mission and realizing its vision of a protected and enhanced watershed. In developing the Phase II Plan, the Watershed Partnership will work to establish priorities, create a detailed plan of management options, and implement improvement projects. Thus, the Phase II Plan will include specific action items to achieve the Watershed Partnership's goals, and these actions may involve recommendations to change the institutional framework within which watershed actions are currently taken.

Federal Legislation

Many federal statutes regulating natural resources, for example the National Environmental Policy Act, are primarily designed to provide a process by which the impacts of federally funded actions to public resources can be assessed and considered with respect to overall public benefits prior to the action. A few, such as the Clean Water Act, regulate specific actions with impacts to natural resources.

Clean Water Act

The Clean Water Act (CWA) is the cornerstone of surface water quality protection in the United States. Section 404 of the Clean Water Act specifically regulates the discharge of materials into "waters of the U.S.," which have historically been interpreted to include wetlands. Filling of any waters of the U.S. requires a permit and mitigation to replace the function and value of the affected waters. However, in the aftermath of the 2001 SWANCC case,[23] almost all of the prairie pothole depressional wetlands in the watershed are currently without 404 protection, according to local regulatory interpretation.

[23]In the SWANCC case, the Supreme Court ruled that the Corps exceeded its authority in asserting CWA jurisdiction over many non-navigable, intrastate waters. These wetlands had been regulated since 1986 under the "Migratory Bird Rule," under the premise that discharging materials into these wetlands, many of which serve as habitat for migratory birds, impacts interstate and foreign commerce. In 2003, the Bush Administration issued a memorandum to the EPA and the Corps, ordering the removal of non-navigable, intrastate waters from their jurisdiction under the CWA where the Migratory Bird Rule provides the sole basis for asserting jurisdiction.

The Clean Water Act also established the National Pollutant Discharge Elimination System (NPDES) permit program to control water pollution by regulating discharge of pollutants into waters of the United States. Industrial, municipal, and other facilities must obtain NPDES permits if their discharges go directly to surface waters. In Texas, the permit program is administered by the Texas Commission on Environmental Quality. Since its introduction in 1972, the NPDES permit program is responsible for significant improvements to water quality.

Coastal Zone Management Act

Though the Coastal Zone Management Act (CZMA) of 1972, Congress recognized the value of the Americas coastal "natural, commercial, recreational, ecological, industrial, and esthetic resources of immediate and potential value to the present and future well-being of the Nation." It called for the development of coordinated, comprehensive state coastal management programs with public input, to help protect coastal resources in the face of competing human uses and increasing pressure from coastal development. CZMA established funding programs for coastal enhancement projects. It established the National Estuarine Research Reserve Program to authorize the designation of selected estuaries as sanctuaries and to promote research in relatively unspoiled areas. Finally, the CZMA requires federal agencies or licensees to carry out their activities in such a way that they conform to the maximum extent practicable with a state's coastal zone management programs.

Endangered Species Act

The Endangered Species Act provides protection of "Critical Habitat" for threatened and endangered species under the jurisdiction of the U.S. Fish and Wildlife Service. Federal actions in areas designated as Critical Habitat must be evaluated to determine their impacts on the species of concern.

Magnuson-Stevens Act

The Magnuson-Stevens Act gives NOAA Fisheries the authority to regulate nearshore waters and substrate necessary for fish spawning, feeding, and growth, or Essential Fish Habitat (EFH), of which a significant amount occurs in Armand Bayou. Although regulatory authority is limited, EFH must be considered in activities within nearshore waters, especially with respect to federal projects.

National Environmental Policy Act

National Environmental Policy Act (NEPA) ensures that all branches of government give proper consideration to the environment prior to undertaking any major federal action that

significantly affects the environment. NEPA requirements are invoked when airports, seaports, highways, parkland purchases, and other federal activities are proposed. Environmental Assessments and Environmental Impact Statements, which are assessments of potential impacts from alternative courses of action, are required from significant federally funded projects.

Rivers and Harbors Act

Section 10 of the Rivers and Harbors Act regulates placement of structures within navigable waters, under supervision of the Army Corp of Engineers. This section regulates any development that would impact the channel of Armand Bayou and any of its tributaries.

National Flood Insurance Act

The National Flood Insurance Program (NFIP) is a federal program, established by the National Flood Insurance Act of 1968, enabling property owners in participating communities to purchase insurance protection against losses from flooding. This insurance is designed to provide an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods.

Federal Agencies and Programs

Environmental Protection Agency

The Environmental Protection Agency (EPA) works to develop and enforce regulations that implement environmental laws enacted by Congress, such as the Clean Water Act and Clean Air Act. EPA is responsible for researching and setting national standards for a variety of environmental programs, and delegates to states and tribes the responsibility for issuing permits and for monitoring and enforcing compliance. Where national

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standards are not met, EPA can issue sanctions and take other steps to assist the states and tribes in reaching the desired levels of environmental quality. The EPA also sponsors several initiatives and grant programs to provide assistance to organizations involved in watershed management, pollution prevention, education, and sustainable development. (http://www.epa.gov/)

National Oceanic and Atmospheric Administration (NOAA)

NOAA Fisheries is a division of the National Oceanic and Atmospheric Administration. NOAA Fisheries works to restore and maintain sustainable fisheries, promote the recovery of protected species, and to protect and maintain the health of coastal marine habitats. The agency conducts research to restore and create fish habitat, reviews coastal development and water projects that may alter or destroy habitat, and recommends measures to offset development and use impacts. NOAA works to achieve its goals by its own actions in cooperation with other resource protection agencies, conservation organizations, and local communities, and by sponsoring national programs such as the Coastal Management Program and Community-Based Restoration Program. (http://www.noaa.gov/)

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) administers regulatory programs and issues permits under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. In addition to its military role, it leads efforts in planning, designing, building, and operating water resources and other civil works projects, such as navigation, flood control, environmental protection, and disaster response. Locally, the Galveston District of the Corps of Engineers leads the Interagency Coordination Team, which was created to address key environmental issues and concerns associated with the widening and deepening project for the Houston-Galveston Navigation Channel. The Beneficial Uses Group is a subcommittee of the Interagency Coordination Team and identifies environmentally and economically responsible

Federal Emergency Management Administration

The Federal Emergency Management Administration (FEMA) has undertaken a massive effort of flood hazard identification and mapping to produce Flood Hazard Boundary Maps, Flood Insurance Rate Maps, and Flood Boundary and Floodway Maps. The maps identify Special Flood Hazard Areas (SFHAs), which are regulated to minimize potential loss of life and property and the economic benefits to be derived from floodplain development. Development may take place within the SFHA, provided that development complies with local floodplain management ordinances, which must in turn meet the minimum federal requirements. Flood insurance is required for insurable structures within the SFHA to protect federal financial investments and assistance used for acquisition and/or construction purposes within communities participating in the National Flood Insurance Program. (http://www.fema.gov/)

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ways to utilize the material dredged from the ship channel expansion project. Efforts include several recent and ongoing efforts to create new islands and restore historic islands that provide important upland, intertidal, and submerged habitats for waterbirds and aquatic species. (http://www.usace.army.mil)

U.S. Department of Agriculture

The U.S. Department of Agriculture is active in natural resource management, particularly through the Natural Resource Conservation Service and the U.S. Forest Service. Both organizations provide resources for natural resource conservation, public land management for conservation purposes, and educational programs. (http://www.usda.gov)

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (USFWS), part of the Department of the Interior, protects America's diverse fish and wildlife resources. Locally, its Texas Coastal Program focuses on restoring and protecting economically, recreationally and ecologically important coastal fish and wildlife habitats through partnerships. By sharing biological knowledge, offering technical assistance in identifying and designing restoration projects, identifying habitat protection opportunities, and providing federal matching funds to implement projects, USFWS Texas Coastal Program biologists play a vital role in supporting and implementing coastal conservation initiatives that succeed through partnerships.
USFWS: (http://www.fws.gov/)
Texas Coastal Program: http://texascoastalprogram.fws.gov/TCPinfo.htm

U.S. Geological Survey

The U.S. Geological Survey (USGS) is a bureau of the Department of the Interior. The USGS serves the nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life. The Water Resources Discipline (WRD) provides reliable, impartial, timely information needed to understand the water resources of the United States. Locally the WRD provides routine monitoring of surface- and groundwater resources, collects site-specific data, and conducts hydrologic investigations for Federal, State, and local agencies. These investigations provide managers with valuable information for decision-making. They also provide data for water-resource modeling and information related to land-surface subsidence, flood-warning systems, freshwater inflows, water and sediment quality, and coastal ecology. Through the USGS cooperative funding program the USGS is able to provide some matching funds for scientific studies, create local partnerships, and provide real-time information available on the Internet at (http://tx.usgs.gov).

Texas State Legislation

Much of Texas' state regulation consists of rules promulgated to implement or augment federal legislation. However, the few unique pieces of legislation with direct implications for the Armand Bayou watershed are described below.

Texas Estuaries Act

In 1999, the Texas Legislature passed the Texas Estuaries Act (HB 2561), making Texas Estuary Programs official programs of the State of Texas. The Texas Estuaries Act recognized the significance of Texas' estuaries, appointed the Texas Commission on Environmental Quality as the lead state agency for estuary programs, instructed other relevant state agencies to participate in the development and implementation of comprehensive conservation management plans for its estuaries, and established the authority of estuary programs to grant and receive state and federal aid in estuary management activities.

Senate Bill 1576

Senate Bill 1576 established the authority of the Houston-Galveston Coastal Subsidence District to regulate groundwater withdrawals in the region to control subsidence induced by excessive groundwater use. Groundwater regulation has been instrumental in curbing the devastating effects of subsidence, of which Armand Bayou provides a dramatic example.

Senate Bill 1

Senate Bill 1, passed in 1997, created a comprehensive state water plan comprised 16 regional water plans under the guidance of the Texas Water Development Board. The state plan will be updated every five years and will serve as a guide for water resource and management policy. The plan will address drought planning, state water project financing, groundwater and surface water management, water use and conservation and funding mechanisms.

Senate Bill 2

Senate Bill 2, passed in 2001, established the Texas Water Policy Council to address Texas water policy issues, to advocate implementation of features within the State Water Plan, and to consider in stream flows and estuary inflow needs. Senate Bill 2 also provides for conjunctive management of surface water and groundwater management, and it ratified groundwater conservation districts created in previous legislation.

Texas State Agencies and Programs

Much of Texas's state regulation consists of rules promulgated to implement or augment federal legislation.

Coastal Coordination Council

The Coastal Coordination Council (CCC) is the policy board for the Coastal Management Program (CMP). The Council is made up of representatives from state resource agencies, local governments, small business, citizens, agriculture, as well as gubernatorial appointees. It adopts uniform goals and policies to guide decision-making by all entities regulating or managing natural resource use within the Texas coastal area. The Council reviews significant actions taken or authorized by state agencies and subdivisions that may adversely affect coastal natural resources to determine their consistency with the CMP goals and policies. In addition, the Council oversees the CMP grants program and the Small Business and Individual Permitting Assistance Program. (http://www.glo.state.tx.us/coastal/ccc.html)

Coastal Texas 2020

Coastal Texas 2020, a GLO initiative is developing a strategic plan to address the challenges to coastal resource management. The process is developing suggestions for legislative changes as well as proposed mechanisms and sources for securing funds to address coastal erosion and other coastal issues. To develop strategies, the Texas General Land Office is seeking input from citizens, business leaders and government officials at the local, state, and federal levels.

(http://www.glo.state.tx.us/coastal/ct2020/index.html)

Galveston Bay Estuary Program

The Galveston Bay Estuary Program of the TCEQ coordinates efforts to implement The Galveston Bay Plan, the Comprehensive Conservation and Management Plan for Galveston Bay. The Estuary Program works with local stakeholders to develop projects and programs to protect and restore Galveston Bay habitats, ensure adequate freshwater inflows to maintain a healthy estuarine system, manage fish and wildlife species, control invasive species, protect and improve water quality, particularly through addressing non-point source pollution, compile and analyze resource data to determine ecosystem health, conduct necessary research, and conduct public outreach and education to promote conservation of bay resources. The Galveston Bay Council, a management committee made up of representatives of state and federal agencies, local governments, citizens, commercial and recreational fishing interests, business and industry, and conservation organizations, is charged with guiding Estuary Program activities to ensure the best use of available resources in implementing The Galveston Bay Plan. (http://gbep.state.tx.us)

Texas Coastal Management Program

The Texas Coastal Management Program (CMP), administered by GLO, provides a framework for coordinating state, local, and federal programs for the management of Texas coastal resources. The CMP was created in the late 1980s to provide for a more coordinated, comprehensive approach to coastal resource management. (http://www.glo.state.tx.us/coastal/cmp.html)

Texas Commission on Environmental Quality

The Texas Commission on Environmental Quality (TCEQ) is responsible for regulating the discharge of contaminants to surface water, groundwater, soil, and air through a wide variety of programs, and conducts public outreach and education in support of these programs. The TCEQ also conducts monitoring and assessment of surface waters to determine compliance with water quality standards. TCEQ conducts Section 401 certification reviews of U.S. Army Corps of Engineers Section 404 permit applications for the discharge of dredged or fill material into waters of the U.S., including wetlands. These certification reviews determine whether a proposed discharge will comply with state water quality standards. TCEQ also administers the Supplemental Environmental Project Program, an innovative approach to resolving enforcement actions and improving environmental quality. Supplemental Environmental Projects are comprised of a wide variety of activities including wetland protection and restoration. TCEQ hosts the Galveston Bay Estuary Program and also provides extensive outreach materials. (http://www.tceq.state.tx.us/index.html)

Texas General Land Office

In Texas, nearshore waters below the mean high-tide mark belong to the state. Texas state law delegates regulation of activities conducted in coastal areas on state-owned lands such as the construction of marinas, piers, docks, etc., to the Texas General Land Office (GLO). Although federal regulations also apply in most of these circumstances, GLO review provides an additional level of scrutiny of impacts to state waters and the public. Any lands that accumulate as a result of activities within waters over state-owned lands generally revert to the State. The General Land Office administers several coastal conservation programs, including the Coastal Management Program and the Coastal Erosion Planning and Response Act Program. (http://www.glo.state.tx.us/)

Texas Parks and Wildlife Department

Texas Parks and Wildlife Department (TPWD) provides outdoor recreational opportunities by managing and protecting fish and wildlife, and their habitat, and acquiring and managing parklands and historic areas. Responsibilities include hunting and fishing, wildlife management areas, law enforcement, state parks and historic areas, conservation and resource protection, and hunter and boater education. In the Galveston Bay watershed, TPWD operates several state parks, historic sites, and wildlife management areas, and has coordinated several large habitat restoration projects. Locally, TPWD leases the Armand Bayou Coastal Preserve from the General Land Office. Also of local interest is TPWD's Recreation Grants Program, which offers matching funds for communities wishing to construct recreational facilities. The Private Lands Initiative and the Wildscapes Program are available to assist landowners in managing their property in an ecologically friendly manner. (http://www.tpwd.state.tx.us/)

Texas Sea Grant College Program / Texas Cooperative Extension

County and marine agents associated with both the Texas Sea Grant College Program (TSG) and Texas Cooperative Extension (TCE) are active in the Armand Bayou area and available to assist with a variety of water quality education programs and demonstrations in the watershed. The Texas Coastal Watershed Program (TCWP) is a regional program of TSG and TCE and has an active watershed education program in the area. (http://www.urban-nature.org)

Regional/Local Entities and Programs

Clear Lake City Water Authority

Clear Lake City Water Authority is a special utility district that provides water and wastewater treatment services to the Clear Lake City area. Its area of responsibility is about 16,000 acres.

Floodplain Administrators

Floodplain Administrators perform duties to minimize flood damages, with responsibilities including but not limited to:

- Reviewing development permit applications to determine whether proposed building site, including the placement of manufactured homes, will be reasonably safe from flooding;
- Reviewing, approving or denying all applications for development permits;
- Reviewing permits for proposed development to assure that all necessary permits have been obtained from those Federal, State or local governmental agencies (including Section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. 1334) from which prior approval is required;
- Interpreting the exact location of the boundaries of the areas of special flood hazards (for example, where a conflict appears to exist between a mapped boundary and actual field conditions);
- Notifying, in riverine situations, adjacent communities and the State Coordinating Agency which is the Texas Commission on Environmental Quality, prior to any alteration or relocation of a watercourse, and submit evidence of such notification to the Federal Emergency Management Agency; and
- Assuring that the flood carrying capacity within the altered or relocated portion of any watercourse is maintained.

Gulf Coast Waste Disposal Authority

Gulf Coast Waste Disposal Authority (GCA) is a non-tax-supported unit of local government dedicated to waste management activities, created by the legislature in 1969. GCA's primary area of jurisdiction is comprised of Harris, Chambers, and Galveston Counties. The Authority may provide services in any part of the State of Texas but coordinates its activities with any other authorities or districts in those areas, which may also be able to provide environmental assistance. (http://www.gcwda.com/)

Harris County Flood Control District

The Harris County Flood Control District (HCFCD) was charged by the Legislature to: control, store, preserve, and distribute the storm and flood waters, and the waters of the rivers and streams in Harris County and their tributaries, for various useful purposes. In addition, HCFCD was directed to reclaim and drain the overflow land of Harris County, conserve forests, and aid in the protection of navigation by regulating the flood and stormwaters that flow into navigable streams. HCFCD reviews and coordinates with developers and other agencies on projects that impact HCFCD facilities to help engineers plan, design, and build facilities that comply with HCFCD design and acceptance criteria, and that propose placement of non-flood control features in HCFCD facilities. (http://www.hcfcd.org)

Harris County Pollution Control

Harris County Pollution Control (HCPC) is a division of the Public Health & Environmental Services Department. The activities of the Pollution Control Division are directed toward ensuring clean air and water for the citizens of Harris County consistent with the protection of public health, enjoyment of property, and the protection of plant, animal, and marine life. The staff conducts investigations, sampling, and surveillance throughout Harris County.

Harris-Galveston Coastal Subsidence District

The Harris-Galveston Coastal Subsidence District (HGCSD) was created by the Texas legislature in 1975. It acts as a groundwater district for this region, and has developed and implemented a plan to regulate groundwater withdrawal and encourage the use of alternate sources, such as surface water. This regulation of ground water pumping has helped to significantly slow subsidence in the Armand Bayou area, one of the major contributing factors of habitat loss and degradation in

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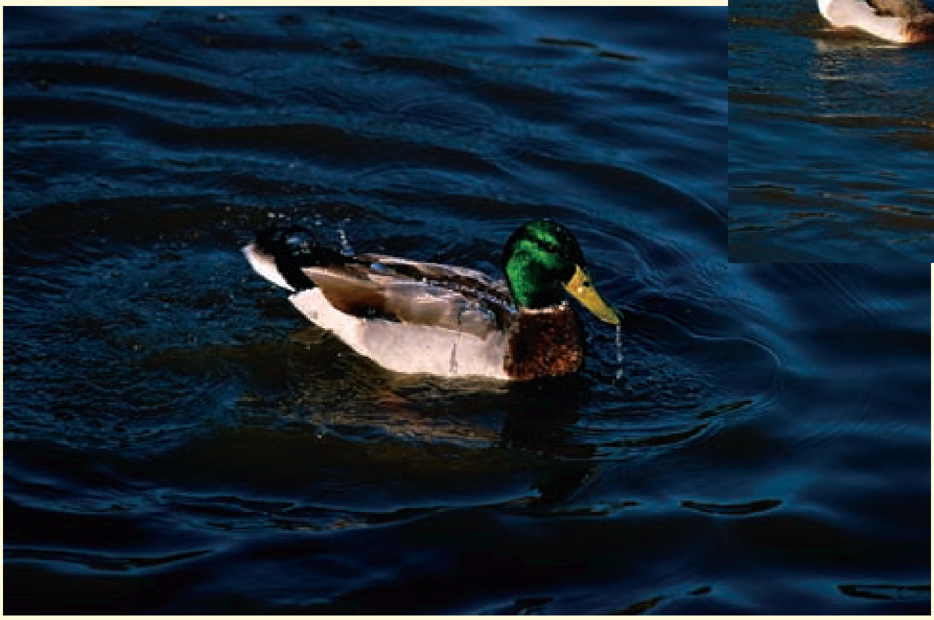
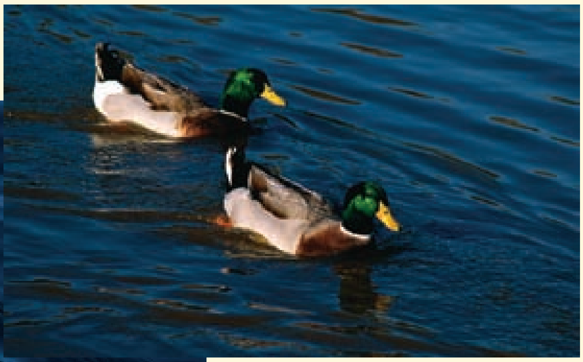




the watershed. HGSCD provides extensive water conservation educational materials. (http://www.subsidence.org)

Houston-Galveston Area Council

The Houston-Galveston Area Council is an association of counties, cities, and school districts in the Gulf Coast Planning Region. It is involved with community and environmental planning, land use planning, air and water quality, and quality of life issues throughout the Houston-Galveston area. (http://www.h-gac.com/)

University of Houston/Clear Lake and Environmental Institute of Houston

The Environmental Institute of Houston (EIH) at the University of Houston-Clear Lake helps people in the Houston region participate more effectively in environmental improvement. Information and technology is obtained and disseminated from research supported by EIH in critical areas including pollution prevention, natural resource conservation, public policy, and societal issues. EIH seeks to expand balanced environmental education based on objective scholarship to empower the entire community to make sound decisions on environmental issues. (http://www.eih.uh.edu/)

Cities

Cities often play a crucial role in conserving community natural resources. The City of Pasadena was instrumental in founding the Armand Bayou Nature Center, and has been involved in efforts to protect greenspace within the watershed, as well as to help control point and non-point source pollution. It has also been active in the effort to develop this comprehensive watershed plan. Cities can offer considerable planning resources, and help with funding in some cases, as parkland acquisition, green space conservation, and pollution control is consistent with meeting the needs of people within local communities.

Non-Governmental Organizations

Armand Bayou Nature Center

The Armand Bayou Nature Center (Nature Center) is charged with maintaining and restoring the Coastal Preserve and lands associated with the Nature Center. The Nature Center also conducts a variety of outreach and educational activities, demonstrating to people of all ages the value of environmental stewardship. (http://www.abnc.org/)

Armand Bayou Watershed Partnership

The Armand Bayou Watershed Partnership (Watershed Partnership) is a collaborative of stakeholders from state agencies, nonprofit organizations, civic groups, academic institutions, local governments, business and industry groups, and utilities. It is developing and implementing a watershed plan for the purposes of protecting, preserving and enhancing the ecological integrity of the Armand Bayou watershed while improving the quality of life in the communities of the watershed.

Association of Bayport Companies

The Association of Bayport Companies (ABC) is a local industry association that includes 55 companies in the Bayport Industrial District, in the east-central part of the watershed (mainly along Bay Area Blvd north of Red Bluff).

Bay Area Houston Economic Partnership

The Bay Area Houston Economic Partnership is a nonprofit organization providing the leadership necessary to stimulate economic development and employment in the area. (http://www.claedf.com/)

Channel Industries Mutual Aid

Channel Industries Mutual Aid (CIMA) combines the fire fighting, rescue, hazardous material handling, and emergency medical capabilities of the refining and petrochemical industry in the Houston Ship Channel area. (http://www.cimatexas.org/)

Clear Creek Environmental Foundation

Clear Creek Environmental Foundation works to preserve and enhance the Clear Creek and Clear Lake environment to maintain its natural resources and beauty for the present and future. CCEF

PHOTOS BY STEPHAN MYERS

provides resources and guidance for education projects around the creek, and develops projects aimed at preserving, enhancing, and returning the natural system and resources to a cleaner and healthier state. (http://www.clearcreekcleanup.org/)

Community Advisory Panels

A community advisory council (CAC) or panel (CAP) is generally a small group of citizens who represent their community and who have made a commitment to meet with the management of the local chemical plant or group of plants on a regular basis to discuss issues of mutual interest. It is an independent body that provides a forum for open and honest dialogue between citizens and plant management. An effort is made to bring the group to a consensus on these issues or to understand why agreement is not possible. Panel members, supported by the plants, take on projects they feel represent the public interest such as promoting 911 services in their community, and developing emergency response and shelter-in-place material and sharing them with local citizens.

Local CACs/CAPs covering interests within the Armand Bayou Watershed include the Bay Area CAP, Deer Park CAC, Houston CAP, La Porte CAC, and Pasadena CAC.

(http://www.ehcma.com/linds.htm#cap)

Corporate Wetland Restoration Partnership

The national Corporate Wetlands Restoration Partnership (CWRP) is a public-private partnership between the federal government, state governments, and private corporations to restore wetlands and other aquatic habitats. The CWRP's objective is to stop and reverse the degradation of America's fresh and saltwater wetlands and other aquatic habitats. In the CWRP, corporations contribute funds to a participating private foundation or state trust fund. In 2002, CWRP opened a chapter in Texas, and has begun to assemble partners and funding to develop and implement conservation projects. (http://www.coastalamerica.gov/http://www.texascwrp.org)

Council for Environmental Education

The Council for Environmental Education (CEE) is a national non-profit educational organization with headquarters in Houston. It provides environmental education programs and services that promote stewardship of the environment and further the capacity of learners to make informed decisions. CEE is a founding co-sponsor of Project WILD, Project Learning Tree, and Project WET, and administers Project WILD, Project WILD Aquatic, and WET in the City. (http://www.c-e-e.org)

East Harris County Manufacturers Association

East Harris County Manufacturers Association EHCMA is a non-profit professional association of approximately 125 chemical manufacturers, refiners, and supporting distribution/terminal facility managers in east Harris County that works to better understand and address community and industry issues/concerns, including risk reduction associated with the operation of associate plants, ensure effective emergency management related to industrial incidents, and better promote the joint economic interests of our industry and local communities. (http://www.ehcma.com/)

Environmental Educators Exchange

The Environmental Educators Exchange (EEE) organizes environmental educators in the Houston area and provides a forum for meeting together and exchanging ideas and information. Several educators in the watershed, including the Texas Coastal Watershed Program and the Nature Center are members of this exchange.

Galveston Bay Foundation

Galveston Bay Foundation works to preserve, protect, and enhance Galveston Bay for multiple uses, through advocacy, education, conservation, and research. Its activities focus on the Galveston Bay watershed, particularly tidally influenced waters. (http://www.galvbay.org)

Houston Audubon Society

Houston Audubon Society is a nonprofit organization that promotes the conservation and appreciation of birds and wildlife habitat. Houston Audubon acquires and maintains critical habitat as bird sanctuaries. It conducts education programs and field trips for children and adults. It readily offers its expertise to efforts to promote conservation of birds and their habitats. (http://www.houstonaudubon.org/)

Joint Task Force

In a cooperative effort to address the EPA National Pollutant Discharge Elimination System (NPDES) Phase I Storm Water Permit requirements, four local entities chose to work together through a Joint Task Force (the "JTF") to prepare and submit a joint permit application. On October 1, 1998, EPA Region 6 issued a NPDES storm water permit to the City of Houston, Harris County, Harris County Flood Control District, and Texas Department of Transportation as co-permittees.

This joint approach has worked well, providing consistency and efficiency among agency programs and economizing permit implementation costs. At the same time, each entity of the JTF is responsible for implementing its own program. EPA has commended the JTF for the quality of its application as well as the consensus, cooperation and partnership building efforts of the four entities. (http://www.cleanwaterclearchoice.org)

Legacy Land Trust

Legacy Land Trust (LLT) is the principal land trust operating in the area. LLT will provide assistance in obtaining conservation easements, and can act as holder of an easement. In some cases, LLT may actually accept title to the land. (http://www.legacylandtrust.org/)

National Wildlife Federation

The National Wildlife Federation (NWF) is a national non-profit . It has partnered with the Texas Parks and Wildlife Department to offer a certification program for backyard wildlife habitat through "Best of Backyard Habitats." Its analysis of the National Flood Insurance program with respect to repetitive losses in floodplains is available on their website. Their Gulf States Natural Resources Center includes Texas as an area of interest. The Center is concerned with restoring rivers and estuaries and conserving wetlands. (http://www.nwf.org/)

The Trust for Public Land

The Trust for Public Land (TPL) works with local communities to develop and implement projects to meet parks and open space needs. TPL also provides assistance through their legal and real estate specialists to help locate and finance public green space. In the Houston-Galveston region, TPL is working specifically to increase public access to Galveston Bay and its tributaries and to save critical habitats in the watershed. (http://www.tpl.org/)

Wildlife Habitat Council

The Wildlife Habitat Council (WHC) helps large landowners, particularly corporations, manage their unused lands in an ecologically sensitive manner for the benefit of wildlife. WHC also works to broaden understanding of wildlife values. Over 120 companies are WHC members as are two dozen conservation organizations, plus many supporters and contributors. WHC opened an office in La Porte in 2001, and is working to develop projects in the Galveston Bay Area. (http://www.wildlifehc.org/)

Tools and Strategies

Habitat

Preservation Options

Although preservation can be an expensive endeavor, various tools are available to conserve natural areas. Several options are available to landowners interested in preserving their land, and several organizations are available to provide assistance.

Purchase

In cases where the landowner wishes to dispose of a property entirely, outright purchase may be employed by conservation interests (government or nongovernmental organizations) to conserve the conservation value of natural areas by fee simple ownership. Purchase may be at fair market value or as a bargain sale (less than fair market value). Bargain sales can result in tax benefits to the seller. Fee simple ownership by a nongovernmental organization (NGO) may remove the property from tax rolls; however, some NGOs make in-lieu fee payments to taxing authorities.

Conservation Easements

A conservation easement is a legal restriction landowners voluntarily place on specified uses of their property to protect natural, productive or cultural features. With a conservation easement, the landowner retains legal title to the property and determines the types of land uses to continue and those to restrict. This agreement permanently restricts activities that would drastically alter conservation values of the land and is not revocable. The entity receiving the easement—a government or NGO—agrees to monitor the land to ensure that the provisions of the agreement are honored. Conservation easements can result in tax savings to landowners.

Purchase of Development Rights

Purchase of Development Rights, or PDR, is a purchase of a conservation easement from a willing landowner. It separates development rights from ownership rights, while generating real income for the landowner based on the market value of the lands. Landowners can sell part or all of the development rights on their property and use the proceeds however they wish, often enabling them to keep their family on the land. Landowners may benefit from reduced taxes, and the opportunities to expand or modernize operations, invest for retirement, and/or settle estates with their PDR proceeds. As with other conservation easements, the government or NGO holding the easement must monitor for compliance.

Public access is not a required component of either conservation easements or PDRs.

Donation

Any of the above may be donated by the landowner, or "sold" at less than market value. This saves the receiving entity funds while providing various tax benefits to the landowner, as well as the benefit to society of open space.

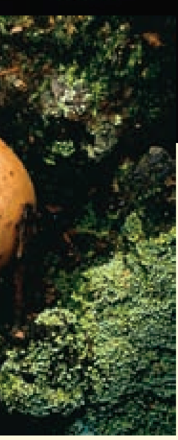
Wildlife Property Tax Valuation

Landowners may request a wildlife management designation of their land if the land was previously appraised as 1-d-1 agricultural land. That is, the land is used for agriculture and has what is known as an agricultural exemption for lowered property taxes, based on the land's productivity value instead of its full market value. To qualify for the wildlife management use appraisal, the land must be actively managed. At least three of seven management strategies must be employed: habitat control, erosion control, predator control, providing supplemental supplies of water, providing supplemental supplies of food, providing shelters, and/or making census counts to determine populations. Another alternative qualification is if the land is used "principally as an ecological laboratory by a public or private college or university."

PHOTOS BY STEPHAN MYERS

Mitigation

Many wetlands are protected under Section 404 of the Clean Water Act. Under USACE's policy of no net loss, wetlands within USACE jurisdiction may be filled uses only after receipt of a permit to do so. Applicants requesting a permit to



fill wetlands must mitigate, or replace the function of the wetlands to be filled based on a ratio determined by the USACE. This ratio depends on the quality of the wetlands to be filled, and the type of mitigation proposed by the applicant. Natural wetlands form over periods of many years, and thus, function and productivity are difficult to replace instantaneously. Consequently, mitigation usually requires creating or enhancing wetlands at a ratio well above 1:1 (units created: units filled).

In some cases, USACE will allow the permanent protection of existing wetlands as mitigation. Although this mechanism arguably violates the no net loss policy since the function and value of filled wetlands are not replaced through preservation, protection of existing wetlands and natural areas may present a desirable alternative to the creation of new wetlands. Again, natural wetlands are almost always more productive than created wetlands. If a mitigation plan includes the permanent protection of special wetlands, of large contiguous tracts of wetlands, and/or productive wetlands that would otherwise be lost in the future, USACE may consider this option.

Mitigation banks are large-scale restoration, enhancement, and/or preservation projects. The mitigation bank sponsor, which could be any type of organization, typically purchases land and restores or enhances wetlands on the site. Credits are then sold to Section 404 permit applicants to meet all or part of the mitigation requirements specified by USACE. Mitigation banking represents a potentially powerful preservation tool, as it presents the opportunity to set aside large, wetland rich tracts of land, which could ultimately pay for themselves as credits are sold to Section 404 permit applicants.

Other

A variety of permutations on the above themes are available, including zoning and park dedication requirements by local governments, trail easements, transfer of development rights, limited development options, and deed restrictions. More information on these options may be found in Open Space, a publication by the National Park Service.

Multiple-Use Open Space

Acquiring land for multiple uses may be an effective means of preserving lands within urban areas. For example, land acquired for detention basins may function as habitat if maintained as wet-bottom detention and jointly used for passive recreation, such as nature observation areas, nature trails, etc. Sensitive areas can still be protected from intensive use, while controlled access provides numerous nature viewing and educational opportunities. The Harris County Flood Control District, in particular, is introducing new concepts for multi-use facilities along creeks and drainage corridors.

Employing multiple-use parks as a means for conserving lands opens a wide range of potential partners and funding sources. Local governments are often willing to participate, as these facilities help to meet recreational needs for nearby communities. Including strong conservation and educational components in this type of project also opens up a range of funding possibilities such as federal conservation programs, as well as state programs such as Texas Parks and Wildlife Department's Outdoor Recreation and Regional Parks grant programs.

FEMA Buy-outs

Lands that are bought through the Federal Emergency Management Agency (FEMA) as buy-outs for flood mitigation may not be developed with permanent structures. These lands are another example of potential for multiple use projects.

Restoration/Management

Prior to settlement, fire was an important part of the local ecology. Fires were the result of lightning strikes and, more frequently, were set by the Native Americans. In addition, low frequency, high intensity grazing by buffalo was also an important component of prairie ecology.

Because of human changes in the natural ecosystem, much of the habitat in southeast Texas quickly becomes infested with brush, unless some kind of habitat restoration and management is employed. Native prairies are overtaken by Chinese tallow thicket, and exotic brush species invade coastal flatwoods.

Restoration management today seeks to mimic pre-settlement ecology. Prescribed burns and grazing and/or mowing are the most important tools for maintaining the prairies. For densely infested areas, removal of pest species may be required – by mechanical or chemical means, and frequently by both.

The Armand Bayou Nature Center (Nature Center) has the most developed restoration and management plan in the watershed. Within the past 5-6 years, they have restored several hundred acres of Chinese tallow thicketized prairies into diverse tall-grass prairies.

One of the most profound habitat losses in the watershed was the disappearance of more than 250 acres of tidal marshes, the result of subsidence-induced drowning, particularly along the main stem of Armand Bayou. An extensive restoration effort, led in large part by ABNC, has to date restored 12 acres of this important habitat.

Assistance

Many sources of assistance in putting together acquisition projects to preserve, restore, and/or manage ecologically valuable lands can be found, including land trusts and natural resource agencies.

Nongovernmental Organizations

Several land conservation organizations are currently active in the Galveston Bay area, such as the Trust for Public Land (TPL), Legacy Land Trust (LLT), and The Nature Conservancy (TNC). Each offers unique sets of expertise and services. TPL, for example, provides assistance in project development, fund-raising, and completing real estate transactions on lands, focusing on lands that provide enjoyment opportunities for people. LLT works with private landowners to place conservation easements on ecologically valuable lands and actually holds the easements, monitoring sites to ensure terms of the easements are upheld.

Additionally organizations such as the National Wildlife Federation (NWF), Environmental Institute of Houston at University of Houston - Clear Lake (EIH), Texas Parks and Wildlife Department, and others provide information about backyard habitats – providing food, water, and shelter for birds and smaller wildlife within neighborhood areas. See Appendix L for organizations active in the Armand Bayou area.

Government

Several government agencies are available to provide assistance in developing conservation projects in the Galveston Bay watershed. Natural resource agencies such as the U.S. Fish and Wildlife Service, Texas Parks and Wildlife Department, NOAA Fisheries, the USDA Natural Resource Conservation Service, and the Galveston Bay Estuary Program offer a variety of resource and project development expertise. Assistance for proper management of private lands is available through the Natural Resources Conservation Service and the Harris County Soil and Water Conservation District. Texas Sea Grant and Texas Cooperative Extension also have programs and information to assist good land management.

Departments within local governments, particularly parks and recreation departments and flood control districts, often share interests with groups seeking to conserve lands. Local governments have the authority to levy in-lieu fees for parkland acquisition, dedicate portions of sales tax revenues, and establish zoning ordinances dedicating areas for parks, etc. And, local governments have the ability to raise funds for park acquisitions through issuing bonds. This mechanism has been used frequently in central Texas for parkland acquisition and protection of lands directly impacting recharge zones for important aquifers.

Local governments often create master plans and ordinance policies for provision of open space to enhance the overall quality of life. In an attempt to balance the built environment with the natural environment, these plans address how housing, transportation, open space, commerce, and environmental systems interrelate and project those relationships into the future. Local governments that conserve portions of these lands as development proposals in such areas are reviewed. The use of new technologies, such as Geographic Information Systems (GIS), helps decision makers analyze multiple layers of information simultaneously to make more informed decisions.

Financing Acquisition, Easements, Restoration, and Management of Open Space

A variety of options are available to help fund the preservation of open space. The Trust for Public Land has a Matrix of Local Finance tools on their web site, (http://www.tpl.org), which has an excellent listing of tools available for local governments. A variety

PHOTO BY JAMEY TIDWELL

of grants are also available for the purchase of public lands.

Several federal and state programs exist for which acquisition for conservation purposes is an eligible activity. The U.S. Fish and Wildlife Service administers the North American Waterfowl Conservation Act and the Coastal Wetlands Planning, Protection, and Response Act programs – two programs for which large amounts of funding are available for wetlands preservation and acquisition. Texas Parks and Wildlife's Outdoor Grants and Regional Park Grants programs also offer large grants for acquisition is an eligible activity. The Texas General Land Office administers the Coastal Management Program and other programs for conservation activities. This agency also maintains a coastal funding website: (http://www.glo.state.tx.us/coastal/funding/index.html). Funding and assistance is often available through local flood control and drainage districts from flood control mitigation, preemptive voluntary buyout, and disaster mitigation programs. Also, several Houston-area foundations maintain endowments that may be used for preservation.

Water Quality

Preservation of Open Space

The preservation of open space is an integral component of preserving and restoring water quality. The slow sheet flow of water allows excess nutrients to be metabolized by vegetation and absorbed. Vegetated open space also retards sediment runoff into water bodies. Generally, open space with healthy ground cover retards rapid runoff into drainage systems and streams. Benefits of open space extend to enhanced wildlife habitat, possible recreation uses, and aesthetic advantages.

Low Impact Development / Natural Processes

Low Impact Development (LID) is a design principle that seeks to decrease the "ecological footprint" of development. LID can cover a wide variety of practices, ranging from environmentally friendly landscaping to natural swales and constructed wetlands. The governing principle behind LID is to provide as many opportunities as possible for water to percolate into the ground, and to provide that opportunity as close to the source as possible. A "thousand drops of water" – many small containments of water – do much more and cost less than large "industrial-sized" detention basins.

Because a large part of the nutrient load in Armand Bayou originates in commercial and residential landscapes, WaterSmart[24] landscapes can contribute greatly to water quality improvement in the bayou. WaterSmart landscapes use native and adapted plants that require fewer fertilizers and pesticides than conventional landscapes do.

Hydrologically functional landscapes can improve water quality even more by mimicking the natural processes that occur in this watershed. Rain gardens, for example, detain water temporarily much as prairie potholes do. Water quality is improved as it passes through a rain garden. Any practice that encourages detention and particularly infiltration of water into the soil could be labeled a "low impact development" practice. Pervious pavement or concrete, for example, allows water to infiltrate into the underlying soil while still providing support for vehicles or other uses. Rain barrels or cisterns catch rainwater that can later be used to irrigate landscapes. Other low impact features include swales and compost beds and filters. For other practices, see (http://www.urban-nature.org/landuse/low_impact_development.htm)

Wastewater Treatment

According to the 2000 Texas Commission on Environmental Quality (TCEQ) water quality inventory, three domestic, one agricultural , and six industrial dischargers are permitted in the Armand Bayou Watershed. Only the domestic wastewater facilities are reported to actually discharge to the watershed, totaling a permitted 11.85 million gallons per day of effluent. The three permitted domestic wastewater dischargers in the Armand Bayou Watershed are:

- City of Houston Metro Central Wastewater Treatment Plant (TCEQ Permit No. 10495-136) located approximately 1.6 miles east-northeast of the intersection of FM 1959 and I-45, adjacent to the southeast corner of Ellington Field, in Houston. The treated effluent is discharged to a HCFCD ditch, thence to Horsepen Bayou, thence to Armand Bayou. The plant's maximum allowable (two-hour peak) discharge rate is 10,417 gallons per minute (23.2 cubic feet per second) and annual average discharge rate is 5 million gallons per day (7.7 cubic feet per second).
- Clear Lake City Water Authority Wastewater Treatment Plant (TCEQ Permit No. 10539-001) located 14210 Middlebrook Drive, approximately 1 mile northeast of the intersection of Bay

[24] WaterSmart, a program of the Texas Coastal Watershed Program, provides outreach and education on issues of water quality, specifically runoff pollution, and water conservation as they relate to residential and commercial landscapes.

Area Boulevard, in Houston. The treated effluent is discharged to Horsepen Bayou, thence to Armand Bayou. The plant's maximum allowable (two-hour peak) discharge rate is 21,528 gallons per minute (47.9 cubic feet per second) and annual average discharge rate is 10 million gallons per day (15.5 cubic feet per second).

- Pecan Plantation Mobile Home Park c/o Heritage Financial Group Inc. (TCEQ Permit No. 12677-001) located approximately 0.25 miles south of the intersection of Spencer Highway and Canada Street in Pasadena. The treated effluent is discharged via pipe to Spring Gully, thence to Armand Bayou. The plant's maximum allowable (two-hour peak) discharge rate is 278 gallons per minute (0.619 cubic feet per second) and annual average discharge rate is 0.100 million gallons per day (0.155 cubic feet per second).

Totals: annual average = 15.100 mgd (23.3 cfs); two-hour peak = 32,223 gpm (71.7 cfs)

Modern technology and permit requirements have greatly improved the water quality of the discharges from domestic and industrial wastewater treatment plants. Small wastewater treatment plants (typically less than 1 million gallons per day discharge) are more likely to experience operations and maintenance problems that may reduce discharge quality.

Permitted dischargers are required to monitor their discharge quality, report violations to the TCEQ, and correct the deficiencies. The TCEQ and the Harris County Pollution Control Division also inspect Armand Bayou watershed wastewater treatment plants. The Gulf Coast Waste Disposal Authority currently offers a technical assistance program for small wastewater treatment plant (less than 1 million gallons per day discharge) operators and managers.

Another source of pollutants to area water bodies originates from aging sanitary sewer collection systems. As this infrastructure degrades, stormwater enters the sanitary sewer system thereby causing a hydraulic overload, which can lead to untreated sewage bypasses and overflows to Armand Bayou and its tributaries. The Harris County Pollution Control Division monitors these excursions and works with the responsible parties to correct the problems.

The three industrial stormwater discharge permits are:

- Sunoco R&M Bayport Plant (TCEQ Permit No. 0002600-000)
- Syngenta Crop Protection (TCEQ Permit No. 0002654-000)
- Equistar Chemicals Pasadena Plant (TCEQ Permit No. 0003029-000)

Storm Water Permitting

Currently, four Armand Bayou Watershed local governments, the City of Houston, the City of Pasadena, Harris County, and the Harris County Flood Control District are required to have a storm water discharge permit as a requirement of the Phase I National Pollutant Discharge Elimination System Storm Water Program for medium (municipal separate storm sewer systems with population between 100,000 and 249,999) and large (municipal separate storm sewer systems with population equal or greater than 250,000) communities.

Proposed Phase II rules will require all the small communities (municipal separate storm sewer systems with population located in an urbanized area, as defined by the Bureau of the Census, or located outside of an Urbanized Area and brought into the program, on a case-by-case basis) in the Armand Bayou Watershed, including La Porte, Deer Park, and Taylor Lake Village, to obtain a permit to discharge their storm water runoff

PHOTO BY STEPHAN MYERS

to area water bodies. It is anticipated that these communities will be required to enter into a general Texas Pollution Discharge Elimination System Phase II storm water permit or obtain an individual permit. Phase II will require the permittees to develop storm water management programs to address six areas as defined by the United States Environmental Protection Agency:

- Public Education and Outreach — a program to distribute educational materials to the community or conduct outreach activities about the impacts of storm water discharges on water bodies and the steps that the public can take to reduce pollutants in storm water runoff
- Public Participation/Involvement — including the public in developing, implementing, and reviewing the storm water management program
- Illicit Discharge Detection and Elimination - a program to detect and eliminate illicit discharges, which are illegal and/or improper connections to storm drainage systems and receiving waters
- Construction Site Runoff Control — a program to reduce pollutants in any storm water runoff from construction activities that result in a land disturbance of greater than or equal to one acre

- Post-Construction Runoff Management in New Development and Redevelopment – a program to address storm water runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one acre that are part of a larger common plan of development or sale
- Pollution Prevention/Good Housekeeping for Municipal Operations – a program to prevent and reduce storm water pollution from activities such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, and storm water system maintenance

As communities implement their storm water management programs, they will determine which control measures are working effectively and which must be fine-tuned to improve water quality. This is an opportunity for local communities to implement important public education and outreach activities that may reduce pollution at the source and incorporate effective best management practices to improve the quality of storm water runoff. Local ordinances that address each of the storm water management programs areas may also be enacted.

Reduced Use of Toxic Products at Homes and Businesses

An effective way to lessen pollutant impacts to area water bodies is to reduce the use of potentially toxic household products. Common products such as cleansers, fertilizers, pesticides, and herbicides may be harmful to the environment if improperly applied, stored, or disposed. These products are termed household hazardous wastes.

Presently, household hazardous waste collection days are held each spring around Earth Day by the Association of Bayport Companies, the City of Deer Park, and UH/Clear Lake. The City of Pasadena intends to implement a continuous collection program instead of a single collection event. The Texas Commission on Environmental Quality's Household Hazardous Waste webpage contains information and resources for proper use and disposal of these potentially damaging materials.

Flooding and Stormwater Management

Tools

A number of options are available to reduce flood damages. Some are termed "structural" tools, while others are termed "non-structural" tools. Examples of each type include:

"Structural" Tools

- **Channelization** consists of widening, deepening, lining, and/or clearing stretches of a channel.
- **Channelization** consists of widening, deepening, lining, and/or clearing stretches of a channel.
- **Detention Basins.** The concept of stormwater detention as an urban stormwater management tool is widely used throughout the Texas Gulf Coast. It is designed to alleviate expedited and increased runoff by collecting the rain that falls on a given site, directing it into a basin, and detaining it from discharging into the stream or storm sewer system until the peak flow of the stream or system has subsided. It then releases the stormwater through a small outflow pipe that is placed at an elevation below peak flow.
- **Bypass Channels**
- **Bridge Evaluations** consist of assessing, removing, replacing and/or modifying bridges.
- **Construction of Levees and/or Flood Walls**
- **Building New Outlets and/or Transition Structures**

"Non-Structural" Tools

- **Buyout of Structures**, including both residential and commercial buildings, removes these structures from harm's way.
- **Flood-Proofing Structures** may include raising homes above flood elevations.
- **Flood Alerts** include warnings and temporary evacuations. The City of Pasadena implemented an automated telephone notification system, capable of notifying residents of an emergency. Residents in specified areas receive a phone call from the system, which plays a recorded message identifying recommended actions in response to the emergency. The system has simultaneous call capability.
- **Floodplain Management and Regulation** includes prohibiting building in the floodplain and/or applying more stringent elevation criteria for new structures.
- **On-Site Measures** can assist by keeping as much water as possible on individual sites, significantly contributing to a reduction in the need for large-scale detention and retention facilities. On-site measures include such things as rain or bog gardens, cisterns, and natural swales. While the individual contributions may be small, the sum of contributions over a neighborhood or subdivision could equal the volume of a standard stormwater detention basin.

Strategies

Cities within the Armand Bayou watershed address flooding of their jurisdictions in a variety of ways. Some of these include: implementing and enforcing stormwater management ordinances which regulate development characteristics, creating design manuals for construction projects, participating in federal, state and regional programs designed to reduce flooding impacts, creating plans to address multi-partner and collaborative opportunities with other local jurisdictions, regional government, educational institutions, non-profits and special purpose districts. See the Policy and Criteria Matrix in Appendix L for area jurisdiction regulations.

FEMA plays a major role in setting national policy to reduce and abate natural and man-made disasters and provides funding for projects. In the context of flood abatement, FEMA ensures that local cities implement appropriate regulations/processes through the Community Rating System. The Community Rating System is a point based system that allows a reduction in flood insurance

premiums for all policyholders of the community if the community adopts and successfully implements certain regulatory standards and adopts processes intended to publicize related information. FEMA provides funding for disaster relief and mitigation, which is distributed through the Texas Division of Emergency Management in accordance with state mitigation priorities.

The waterways of the region form an integral and distinguishing part of the local landscape, offering distinctive vistas, whether in their original natural condition, or sculpted by modernization. Entities working in the Armand Bayou watershed utilize several strategies for reducing the risk of flooding from these waterways, with appropriate regard for community and natural values.

The most comprehensive effort of the Harris County Flood Control District (HCFCD) to actually reduce flood levels and flood damages comes from implementing projects, which HCFCD carries out on its own and through partnerships with others. Foremost among several key components of HCFCD's Capital Improvement Program is District's partnership with the U.S. Army Corps of Engineers. This association has helped bring about federal funding assistance for flood damage reduction projects. HCFCD also funds its own Regional Program of projects.

Prevention

Many of the low impact development measures discussed previously serve to detain stormwater on the site. Using compost to increase soil permeability, cisterns, pervious pavement, etc, all serve to increase infiltration into the soil, which not only improves water quality, it also decreases the speed and amount of runoff coming off of a site. No institutional structure or program exists for promoting prevention through on-site measures.

Within city boundaries, local floodplain administrators conduct hydrological engineering analysis to ensure that new development does not exacerbate existing flooding problems by adding an additional burden to the primary drainage system. HCFCD assumes this role outside of local jurisdictions and within some jurisdictions that defer to HCFCD for that purpose. Strict adherence to the FEMA guidelines is recommended for existing and new developments in the storm surge areas.

One initiative, HCFCD's Frontier Program, aims for acquisitions that reserve land in developing areas. This program prevents dramatic increases in impervious surface cover and thus reduces flooding. Another initiative of HCFCD, known as the Tropical Storm Allison Recovery Project (TSARP), will help increase understanding of the areas at risk of flooding from the primary bayou systems. Jointly funded by FEMA and HCFCD, TSARP will result in fully updated computer models and floodplain maps for all of Harris County. TSARP will generate a new set of Flood Insurance Rate Maps. The upshot of TSARP will be a more disaster resistant community that is better prepared for the next major flooding event.

Detention

Within city boundaries, local floodplain administrators regulate construction of detention facilities to mitigate increases in downstream discharge. HCFCD again assumes this role outside of local jurisdictions and within some jurisdictions that defer to HCFCD for that purpose. Detention is used to varying degrees by different jurisdictions. Communities in the watershed require detention for large residential developments, and most require detention in some form for even small commercial development. Several onsite and subregional detention facilities are located in the watershed. Some of these are on upper Horsepen Bayou, the Ellington Air Force Base, and near the actively developing Beltway 8 Fairmont Parkway area.

In a private analysis for Friendswood Development Company, potential benefits of detention along the lower reaches of Horsepen Bayou were investigated, but no benefits in lowering peak flows were found.

In 1996, HCFCD partnered with the City of Pasadena to produce an analysis of potential measures that would help contain the 100-year flood frequency event. The report, done by Klotz and Associates Inc., quantified the amount of existing right of way along the main stem of Armand Bayou, and quantified the amount of remaining undeveloped sites in the watershed that would be suitable for detention pond construction. The report also recommended actions to increase the flow capacity of the main stem of the bayou coupled with acquisition of the identified tracts to provide additional detention. Specifically, the report recommended a total of 1,373 acre-feet of detention volume be constructed on 6 sites. No analysis of potential measures was conducted outside of Pasadena in this report.

Drainage

HCFCD and local jurisdictions have worked to create a network of channelized streams throughout the county, including the upper reaches of Armand Bayou and its tributaries. Channelization accelerates the movement of water out of the neighborhoods, reducing the threat of flooding in the vicinity, but may increase flooding risk downstream. Extensive maintenance is performed by the jurisdictions and by HCFCD of their respective channel systems to ensure that the intended flood carrying capacity is available when the rains come. Downstream of Bay Area Boulevard, flood reduction and management options are limited in addition to being prohibitively expensive.

Public Outreach

Almost every organization involved in water, watershed, or water quality work in the Armand Bayou area deals at least tangentially with public education and outreach. Locally existing outreach programs are listed in Appendix I, Appendix J, and Appendix M. However, as previously stated, while a substantial amount of outreach activity occurs in the watershed and surrounding areas, the efforts lack a unified approach. The efforts are somewhat of a "shotgun" approach, scattered and unorganized.

Nationally, however, several examples of well-organized outreach programs may be found, as well as organizations dedicated to supporting such efforts. Some of the more effective, well-known ones are listed in Appendix M.

Monitoring and Measuring Progress

Habitat

It is important to monitor overall changes in habitat to know whether critical habitat areas are threatened. Remaining habitat can be monitored either in terms of quality or quantity. Quality monitoring involves measuring specific indicators, such as biodiversity, percent cover, or range quality over time. This kind of monitoring requires a fair amount of scientific rigor to insure that results are comparable over time.

Monitoring the quantity of remaining habitat is comparatively simple. Once a habitat map has been established (as it has for the Armand Bayou watershed), changes in habitat coverage and composition can be monitored. Tools can include aerial photography, satellite imagery, and field surveys.

To be effective, monitoring data should be stored and manipulated in a geographic information system (GIS). The data can be stored geographically (e.g., geo-referenced), and maps of change can easily be generated.

Water Quality

Water quality monitoring involves the collection of data on many physical, chemical, and biological parameters that indicate the health of the aquatic environment. Water quality measurement is an assessment of the collected data and draws conclusions as to whether water bodies are meeting standards, as set by the Texas Commission on Environmental Quality (TCEQ) and approved by the United States Environmental Protection Agency (EPA). The State of the Watershed, Water Quality section in this plan lists such parameters that were assessed for Armand Bayou.

Water quality in the Armand Bayou Watershed is monitored by various entities, including the TCEQ, City of Houston Health and Human Services Department, and by local citizen monitors through the Texas Watch Program. Each entity has its own set of monitoring stations, which are coordinated by the local Texas Clean Rivers Program partner agency, the Houston-Galveston Area Council. The Clean Rivers Program is a state-fee funded monitoring, assessment, and public outreach program that provides the opportunity to approach water quality issues within a watershed at the local and regional level through coordinated efforts among diverse organizations.

Volunteer monitoring also has a role. The Texas Watch Program is a network of trained volunteers and supportive partners working together to gather information about the natural resources of Texas and to ensure the information is available to all Texans. Volunteers are trained to collect quality-assured information that can be used to make environmentally sound decisions. The program is administered by Texas State University through a cooperative agreement with the TCEQ and EPA.

The water quality is assessed by the TCEQ on a biennial basis as a part of the state's water quality inventory, or "305(b) report." The biennial assessment also includes a listing of those water bodies that do not meet their assigned uses, known as the "303(d) list." These uses can include aquatic life use, contact recreation use, noncontact recreation use, drinking water supply use, fish consumption use, and oyster waters use.

Flooding and Stormwater Management

Flood Level Gauges

The Harris County Flood Control District and the Harris County Office of Emergency Management (HCOEM) maintain a system of rainfall and stream level gauges in Harris County. HCOEM and HCFCD use the gauge information to work with the local office of the National Weather Service to generate flood warnings during potential flooding events. The system presently includes 5 gauges within the Armand Bayou watershed. Real time gauge data can be accessed at www.hcoem.org.

Flood Damage/Debris Lines Reports

The Harris County Flood Control District, the Permit Office of the Harris County Department of Public Infrastructure, and the various cities within the watershed prepare flood damage and debris line reports after significant flooding events. The reports are generated by physical inspection of flooded areas after floodwaters recede. Personnel from the agencies will drive the flooded areas looking for evidence of flooding, including high water marks on structures and damaged carpet, sheetrock and other items recently removed from the flooded structure. Individual reports are maintained by each of these entities, and are available for review at their offices.

Public Outreach

Dr. Steven Klineberg, of Rice University's Sociology Department, and his students have conducted annual extensive surveys of the Galveston Bay area about environmental awareness. Such baseline information is crucial to determine true impact.

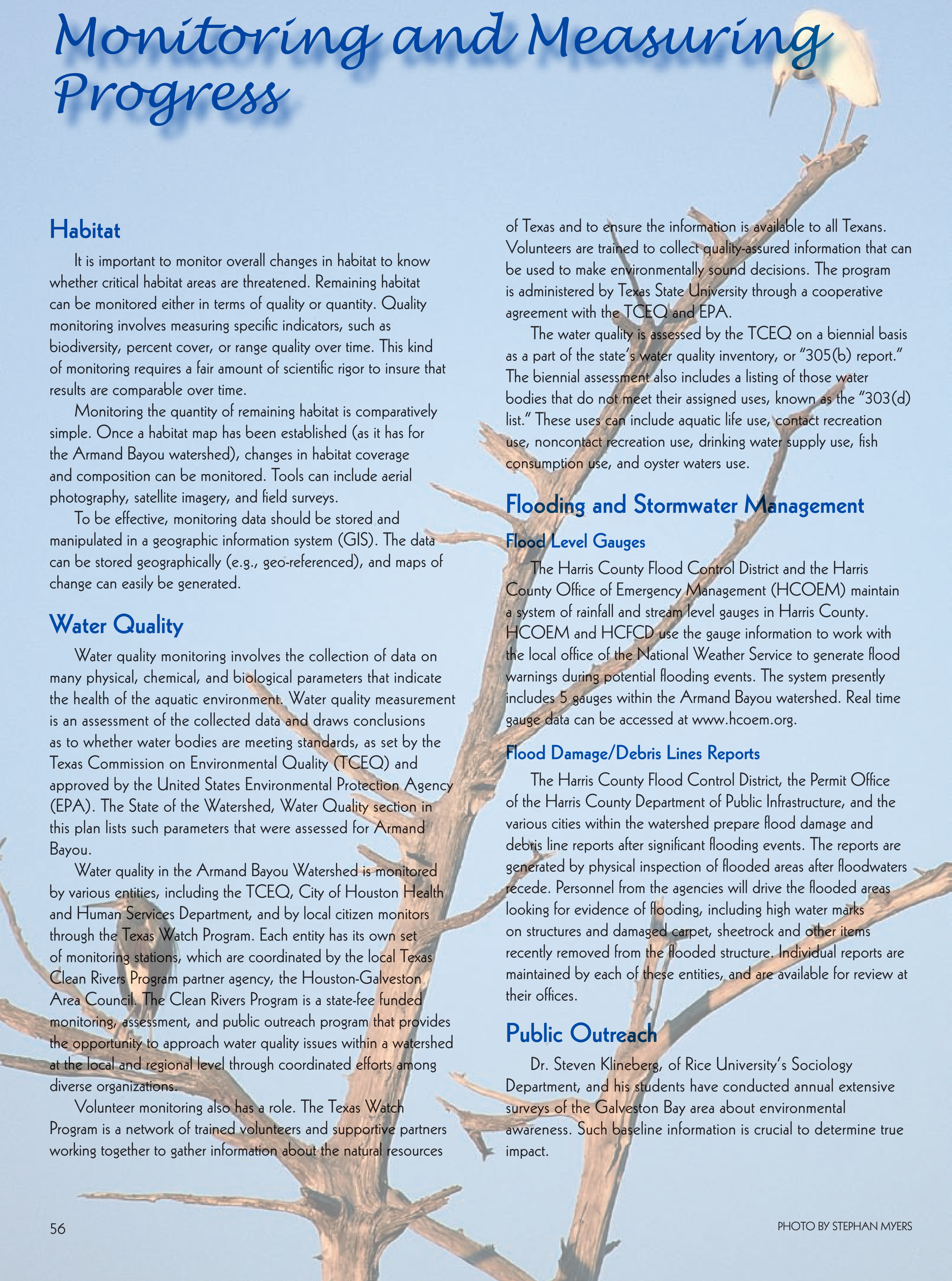


PHOTO BY STEPHAN MYERS

Data Gaps

Habitat

Many data gaps exist in knowledge of the habitat of Armand Bayou. Among the information needs are:

- A better understanding of the phytoplankton community of the Bayou as it relates to sediment/water column nutrient fluxes, and compared to a non-enriched system to elucidate the water quality problem and its likely impact on fisheries.
- A benefit/cost analysis of how to reduce nutrient flow into the Bayou (water quality is a fishery habitat parameter).
- A model of anthropogenic nutrient and pollutant inputs into the Bayou with sinks and outflows also identified, also including modeling of pre-settlement flows into the Bayou as well.
- A comprehensive map of wetland mitigation and other habitat restoration/creation sites and a report on their success.
- A new wetlands inventory map and a map of all ditches and waterways that make up the watershed.
- A wildlife habitat conservation plan that outlines areas of particular value and options for conserving them and connecting them to the core area (ABNC).
- Identification of potential plant and animal reintroductions that could benefit the watershed.
- Economic and ecological benefits of natural habitats.

Water Quality

The Texas Surface Water Quality Standards were designed to cover a large range of water bodies throughout the state, and represent a minimum for regulatory purposes. They are not an index for determining estuarine health and so may not capture the goals of the Armand Bayou Watershed Partnership. Appropriate standards for various water quality parameters from reference watersheds, including dissolved oxygen, should be collected and utilized in the analysis of the health of the watershed. Currently, TCEQ is collecting such data. In addition to this overarching need, other needs include:

- Automated 24-hour dissolved oxygen sampling to better capture critical dissolved oxygen minima that impact the aquatic life community.
- More frequent sampling of metals and organic compounds in water and sediment.
- Human health risks of contact recreation activities.
- Bacterial source tracking studies to determine sources of, and develop best management practices to reduce, bacteria concentrations.
- Information and analysis of coastal tidal waters (especially flat areas), considering the changes in stream gradients caused by subsidence
- Data on the efficiency of local best management practices for storm water quality improvement are needed. For example, many of the engineering practices related to storm water detention and infiltration may be inappropriate for local topography, soil types, and rainfall regimes.
- In lieu of event mean concentration estimations, primary data on storm water runoff quality.
- Storm water runoff contaminant loading, such as sediment, based upon the primary data and studies on the cumulative impacts of such loading.
- Information on long-term effects of sediment accumulations in detention basins, including data regarding hazardous substances and effects on groundwater.

Flooding and Stormwater Management

The choice of the most effective methodologies of stormwater management to reduce flooding and the search for the most publicly acceptable options has generated vigorous discussions. As stormwater management authorities search for methods that combine effectiveness with public acceptability, watersheds become a laboratory for determining methods that will optimize habitat and open space while maximizing flood reduction. The issues of channelization vs. detention, choices of construction material, choices of vegetative ground cover, and the use of open space to manage stormwater are constantly being reviewed. As stormwater management evolves beyond concrete and channelization, it will yield data on the effectiveness of new techniques to reduce flooding and preserve habitat.

Public Outreach

Little to no research has been done to date on outreach in the Armand Bayou watershed and its effectiveness, nor of what people know about the watershed.

Next Steps

This Phase I Armand Bayou Watershed Plan presents the current state of the watershed, the current management programs and practices, and the current tools and strategies used throughout the watershed. The Phase II Armand Bayou Watershed Plan will build on the Phase I plan to develop a more complete plan that will begin to implement the mission and vision of the Watershed Partnership. The Phase II Plan will identify specific objectives and tasks in ways that build partnerships, coordinate actions, leverage resources, and enhance opportunities for success. Development of the Phase II Plan will involve reaching out further into the watershed community to expand involvement, participation, and stewardship.

The Steering Committee and Watershed Partnership recently adopted formal procedures for their structure and operation to be used throughout the Phase II Plan development process. It will begin with the publication, release, and distribution of Phase I Plan, Executive Summary, and informational brochures. Considerable public outreach will be conducted to promote public awareness and education about the Armand Bayou watershed. The existing subcommittees will continue to operate and others may be added as needed. It is anticipated that the already strong and broad participation will strengthen as the Phase I Plan is publicized and Phase II plans begin to develop. Target dates for milestones and completion of the Phase II Plan will be generated as part of the plan development process.

PHOTO © CLIFF MEINHARDT

Appendix A. List of Acronyms

µmhos/cm	Micromhos per centimeter, a unit of measure for conductivity
µg/L	Micrograms of solute per liter, a unit of measure for concentration
ABC	Association of Bayport Companies
ABNC	Armand Bayou Nature Center
ABWWG	Armand Bayou Watershed Working Group
BAHEP	Bay Area Houston Economic Partnership
BFE	Base Flood Elevation
BMP	Best Management Practice
CAC	Citizens' Advisory Council
CAP	Community Advisory Panel
CCC	Coastal Coordination Council
CIMA	Channel Industries Mutual Aid
CIP	Capital Improvement Program, of the Harris County Flood Control District
CRS	FEMA's Community Rating System
CWA	Clean Water Act
DO	Dissolved Oxygen
EA	Environmental Assessment
EFH	Essential Fish Habitat
EHCMA	East Harris County Manufacturers Association
EIH	Environmental Institute of Houston
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERM	Effects Range - Median
ESA	Endangered Species Act
FBFM	Flood Boundary and Floodway Map
FEMA	Federal Emergency Management Agency
FEMD	Harris County Facilities and Emergency Management Department
FHBM	Flood Hazard Boundary Maps
FIRM	Flood Insurance Rate Map
GBC	Galveston Bay Council, of the Galveston Bay Estuary Program
GBEP	Galveston Bay Estuary Program, of the Texas Commission on Environmental Quality
GBF	Galveston Bay Foundation
GBIC	Galveston Bay Information Center
GCWDA	Gulf Coast Waste Disposal Authority
GLO	Texas General Land Office
HCFCD	Harris County Flood Control District
HCOEM	Harris County Office of Emergency Management
HCPCD	Harris County Pollution Control District
HCSWCD	Harris County Soil and Water Conservation District
H-GAC	Houston-Galveston Area Council
HGCSD	Harris-Galveston Coastal Subsidence District
HHW	Household Hazardous Waste
HMGP	Hazard Mitigation Grant Program
JTF	Joint Task Force
LID	Low Impact Development
LIDAR	LIght Detection And Ranging
LLT	Legacy Land Trust
mg/L	Milligrams (1/1,000 gram) per liter, a unit of measure for concentration
msl	Mean Sea Level
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Protection Act
NFIP	National Flood Insurance Program
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWF	National Wildlife Federation
OWOW	EPA's Office of Wetlands, Oceans, and Watersheds
PDR	Purchase of Development Rights
PPT	Parts Per Thousand
SAV	Submerged Aquatic Vegetation
SEP	Supplemental Environmental Project Program of the Texas Commission on Environmental Quality
SFHA	Special Flooding Hazard Area
SWANCC	Solid Waste Agency, of Northern Cook County Illinois
SWMP	Stormwater Management Program
TCE	Texas Cooperative Extension, of Texas A&M University
TCEQ	Texas Commission of Environmental Quality
TCWP	Texas Coastal Watershed Program, of Texas Sea Grant and Texas Cooperative Extension
TCWRP	Texas Corporate Wetland Restoration Program
TDR	Transfer of Development Rights
TGLO	Texas General Land Office
TNC	The Nature Conservancy
TNRCC	Texas Natural Resource Conservation Commission (now Texas Commission on Environmental Quality)
TPDES	Texas Pollution Discharge Elimination System
TPL	The Trust for Public Land
TPWD	Texas Parks and Wildlife Department
TSARP	Tropical Storm Allison Recovery Project
TSG	Texas Sea Grant College Program
TSS	Total Suspended Solids
TWDB	Texas Water Development Board
TWPC	Texas Water Policy Council
UA	Urbanized Area
UHCL	University of Houston - Clear Lake
USACE	U.S. Army Corps of Engineers
USDA NRCS	Natural Resources Conservation Service, of the U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service, of the U.S. Department of the Interior
USGS	U.S. Geological Survey
WHC	Wildlife Habitat Council

Appendix B. Glossary

303(d). Refers to section 303(d) of the Clean Water Act. Every two years, states must assess the quality of their water and submit a report to the EPA detailing the extent to which each water body in the state meets water quality standards. The TCEQ publishes this assessment as the Texas Water Quality Inventory and 303(d) List. The inventory gives the status of all surface water bodies of the state that were evaluated for the given assessment period. The 303(d) List is an important management tool produced as part of the assessment. It identifies waters for which preventive measures are not sufficient to achieve established water quality standards. These waters are often referred to as "impaired" water bodies.

Algal Bloom. Algae are microscopic plants, and most are aquatic. Algal blooms occur in both marine and freshwater environments when an algal species out competes other species and reproduces rapidly. Algal blooms can be caused by multiple factors, but usually by excess nutrients, which cause algae growth and reproduction to increase dramatically into a bloom. In other instances, something may change in the environment so that certain algae can out compete the other algae for food, which can result in a bloom of the algae with the advantage. An algal bloom can kill fish and other aquatic life by decreasing sunlight available to the water and by using up all of the available oxygen in the water. A harmful algal bloom (HAB) is a special algal bloom that produces harmful toxins detrimental to plants and animals.

Best Management Practice (BMP). Structural and nonstructural techniques that store or treat stormwater runoff to reduce flooding, remove pollutants, and provide other amenities.

Biological Oxygen Demand (BOD). The amount of oxygen consumed by the natural decomposition of biological matter or chemical reactions in the water column. BOD is often used as a measure of organic pollutants discharged into streams. BOD loadings tend to deplete oxygen water in the receiving body as the organic material is decomposed, lowering dissolved oxygen content.

Chlorophyll-a. The primary photosynthetic pigment of plants that gives them their green color. Measured as an indicator of water quality. High levels of chlorophyll-a may indicate an algal bloom.

Coastal floodplain flooding. (Also called **"storm surge flooding."**) When the storm surge associated with a hurricane or tropical disturbance pushes water onshore and inundates low lying coastal areas.

Conservation easement. A legally enforceable agreement between landowner(s) and a conservation group or government body, allowing the landowner(s) to continue ownership and most/all current uses while devoting the land to specified long-term conservation uses.

Conductivity. The ability of a water sample to conduct electricity. Conductivity is related to salinity, and is a measure of the concentration of dissolved solids or salts in the water.

Cone of Subsidence. The cone-shaped subsidence of the water table caused by overwithdrawal (overpumping) of groundwater, which lowers the water table.

Dissolved Oxygen (DO). The concentration of oxygen dissolved in the water column, and available for biochemical activity. The amount of water that can dissolve in water varies with salinity and temperature, such that cold, fresh water can hold more oxygen when fully saturated than warm, salt water

Ecological footprint. The extent and breadth of impacts that an activity has on the surrounding ecosystem. For example, the placement of a wide, well-maintained utility easement through the middle of a contiguous, pristine forest would be considered to have a much larger ecological footprint than the clearing of a few trees at the forest's edge for a roadsign. The easement would bisect a previously intact ecosystem, create extensive forest edge, and provide opportunities for penetrations of new species such as the Brown-headed Cowbird, all of which can significantly alter the system's ecology, while removing a few trees at the forest's edge would not likely have serious ecological impacts.

Estuary. A semi-enclosed system comprising a transition from freshwater to marine environments, where freshwater from rivers, bayous and tributaries mixes with salt water from an ocean. This mixing provides a unique environment that houses diverse flora and fauna. The Galveston Bay estuary is a highly productive, nutrient rich ecosystem that provides critical nursery areas for juvenile marine organisms such as shrimp, oysters, crabs, and numerous fish species.

Estuarine. Adjective, of or relating to an estuary. Example: estuarine ecology.

Eutrophic. Characterized by an excess accumulation of nutrients, increased algal production, and low dissolved oxygen levels.

Fecal coliform bacteria. Bacteria found in the intestinal tracts of warm-blooded animals. These organisms are used as indicators of fecal pollution and the possible presence of waterborne pathogens.

Flood Damage Reduction Plan (FDRP). Map developed to lessen the damages to an area caused by flooding that can include a combination of structural and non-structural elements.

Flood Insurance Rates Map (FIRM). Map showing the areas subject to flooding from a primary flooding source, typically major rivers, channels and their tributaries, and are meant to help determine the risk of flooding for a property. The FIRMs show floodplains based on a 1% flood, and sometimes floodplains based on a 2% flood

Floodplain. A strip of relatively level land bordering a stream, built of sediment carried by the stream and dropped in the slack water beyond the influence of the swiftest current. It is called a living floodplain if it is overflowed in times of high water, or a fossil floodplain if it is beyond the reach of the highest flood.

Habitat. (Also called "**natural area**.") Habitat refers to natural areas that are suitable for wildlife, and that retain at least some of their natural character.

Impaired waterbody. A waterbody is impaired when it does not support the uses established for it by the Texas Surface Water Quality Standards. Impaired waterbodies are listed on the Texas 303(d) list.

Impervious cover. Groundcover, natural or manmade, that does not allow storm water to infiltrate into the ground. Examples of impervious cover include pavement, buildings and rock.

Indicator. Measurable quantity of a chemical (i.e., elements or compounds) or biota (i.e., organisms, species, or communities) that can be used to evaluate the relationship between pollutant sources and their impact on environmental conditions.

Low Impact Development (LID). A technique to maintain or mimic pre-development runoff conditions through a variety of small landscape features that infiltrate, filter, store, evaporate, and detain runoff close to its source. LID addresses stormwater through small, cost-effective landscape features located at the lot level.

Macroinvertebrate. Macroinvertebrates are invertebrate animals, animals without vertebral columns or spinal chords, that are visible to the naked eye. Those that inhabit the bottom of water bodies are referred to as benthic macroinvertebrates, or benthos. Macroinvertebrates are critical links in the food webs of aquatic systems. As many are sensitive to pollutants, and are often fairly immobile compared to fish species, they are useful indicators of water quality.

Main stem. The major channel of a waterbody into which tributaries flow.

Microgram (μg). One one-millionth of a gram; 10^{-6} gram.

Mima mound (Also called **"pimple mound."**) Circular to elliptical mounds up to 150 feet in diameter and two to four feet in height from the general ground level. These features are often found in association with freshwater depressional wetlands in prairie pothole complexes.

Natural area. (Also called "**habitat.**") Habitat refers to natural areas that are suitable for wildlife, and that retain at least some of their natural character.

Nitrates. Nitrates are compounds containing the nitrate ion (NO3-). Nitrates are important nutrients for green plants.

Nitrites. Nitrates are compounds containing the nitrite ion (NO2-), often produced by bacterial processing of ammonia. Nitrites are toxic to many animal species, as they bind to hemoglobin and interfere with respiration.

Non-point source (NPS). Pollution originating from many diffuse sources rather than one specific, identifiable source. Non-point source pollution is caused by rainfall or snowmelt. As the runoff moves, it picks up and carries away natural and man-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and groundwater.

Non-point source pollution. Pollution originating from many diffuse sources rather than one specific, identifiable source.

Nutrient. Any substance used by living things to promote growth. This term is usually applied to nitrogen and phosphorous in water and wastewater, but can also be applied to other essential and trace elements. Excess quantities of nutrients can contribute to water quality problems and eutrophication.

Open space. Any undeveloped area, and includes natural habitat as well as parks, pastures, and water.

Overbank flooding. (Also called **"shallow floodplain" flooding**). Occurs when the water level in stream or channel rises to a level higher than the channel bank, inundating the area adjacent to the channel.

Pervious cover. Groundcover, natural or manmade, that allows storm water runoff to infiltrate into the ground.

Pheophytin-A. One of many photosynthetic pigments. Measured as an indicator of water quality.

Phospohorus (Total P). Phosphorus is an essential nutrient in plant growth. Total phosphorus is a measure of all the various forms of phosphorus that are found in a water sample. Excess phosphorus can contribute to algal blooms and eutrophication.

Photosynthesis. The process by which many plants and algae convert energy in sunlight to chemical forms of energy that can be used by biological systems.

Phytoplankton. Photosynthetic aquatic organisms carried about by water motion. Phytoplankton are primary producers and form the foundation of the food chain in many ecosystems.

Pimple mound. (Also called **"mima mound**.") Circular to elliptical mounds up to 150 feet in diameter and two to four feet in height from the general ground level. Pimple mounds are often found in association with freshwater depressional wetlands in prairie pothole complexes.

Point source. Any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, discrete fissure, or container. It also includes vessels or other floating craft from which pollutants are or may be discharged. By law, the term "point source" also includes concentrated animal feeding operations, which are places where animals are confined and fed.

Point source pollution. Pollutants that come from a concentrated, discernable originating point, such as a pipe from a municipal wastewater treatment plant or factory or a large registered feedlot with a specific point of discharge.

Prairie pothole. Circular to irregular, undrained depressions scattered on the ground surface. These features are most often remnants of ancient river channels, partially filled with sediments, and abandoned by natural migration of the river channels. These potholes seasonally fill with water and are important in retaining water during rain events, processing pollutants and retaining sediments to improve the quality of water that eventually winds up in streams, and provides important habitat for a diversity of plant and animal species, notably waterfowl.

Rain Garden. A garden used to capture water during rainfall events. These gardens are usually planted with wetland or bog plants, which help in processing pollutants and trapping sediments, resulting in cleaner water runoff.

Respiration. In this document, reference is made to cellular respiration. Cellular respiration is the use of oxygen by living organisms during metabolic processes that generate energy.

Riparian. Pertaining to the banks of a stream.

Runoff. See **Stormwater Runoff**.

Salinity. The concentration of dissolved salts in water.

Secci Depth. The depth at which a standard black-and-white disc is indistinguishable from the surrounding water. Secci depth is used as a measure of water clarity, or turbidity (see definition below).

Sediment. Particles of sand, clay, silt, and plant matter deposited in slow moving areas of streams and rivers and in reservoirs and estuaries.

Storm surge flooding. (Also called **"coastal floodplain" flooding.**).Occurs when the storm surge associated with a hurricane or tropical disturbance pushed water onshore and inundates low lying coastal areas.

Shallow floodplain flooding. (Also called **"overbank" flooding.**) Occurs when water level in stream or channel rises to a level higher than the channel bank, inundating the area adjacent to the channel.

Stormwater. Runoff from land and impervious areas such as paved streets, parking lots, and building rooftops during rainfall and snow events.

Stormwater runoff. (Also called "**runoff.**") Rainfall that does not evaporate or infiltrate into the gound but instead flows across land and into waterbodies

Total Maximum Daily Load (TMDL). Maximum amount of pollutant loading that a waterbody segment can receive and still support water quality standards/designated uses.

Toxicity. The degree to which a substance is harmful to the health of humans or other organisms.

Trophic. Trophic state of a waterbody refers to its nutritional status.

Various classification schemes exist that group waterbodies into discrete trophic (quality) states along a continuum from oligotrophic (poorly nourished) to mesotrophic to eutrophic to hypereutrophic (overnourished).

Turbidity. A measure of the cloudiness of water, which is a function of the amount of suspended material, both organic and inorganic. Typically turbidity is measured by determining the extent to which light is attenuated in passing through water.

Water column. Refers to the vertical region in a water body anywhere between the surface and the bottom, but not inclusive of the surface or bottom.

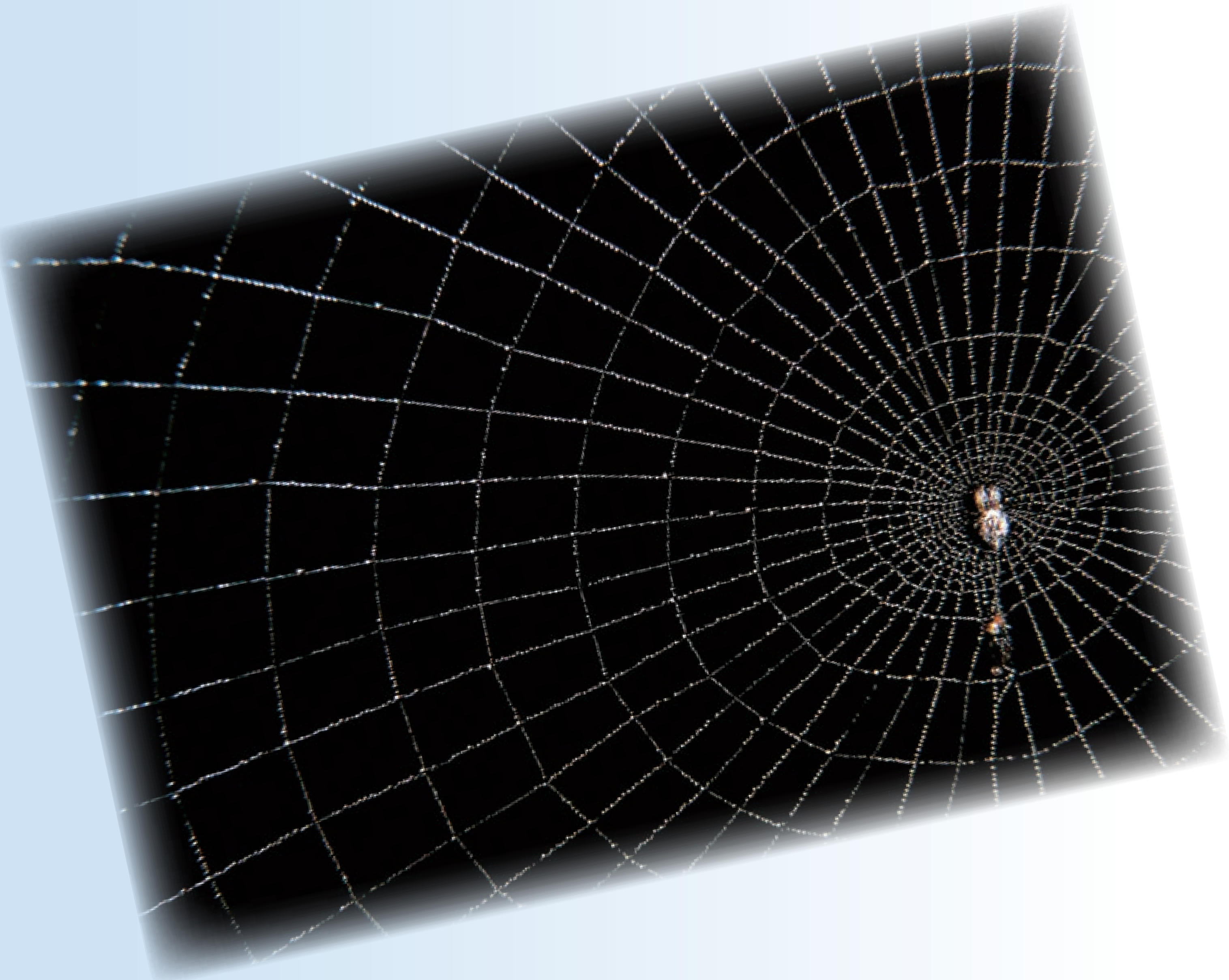
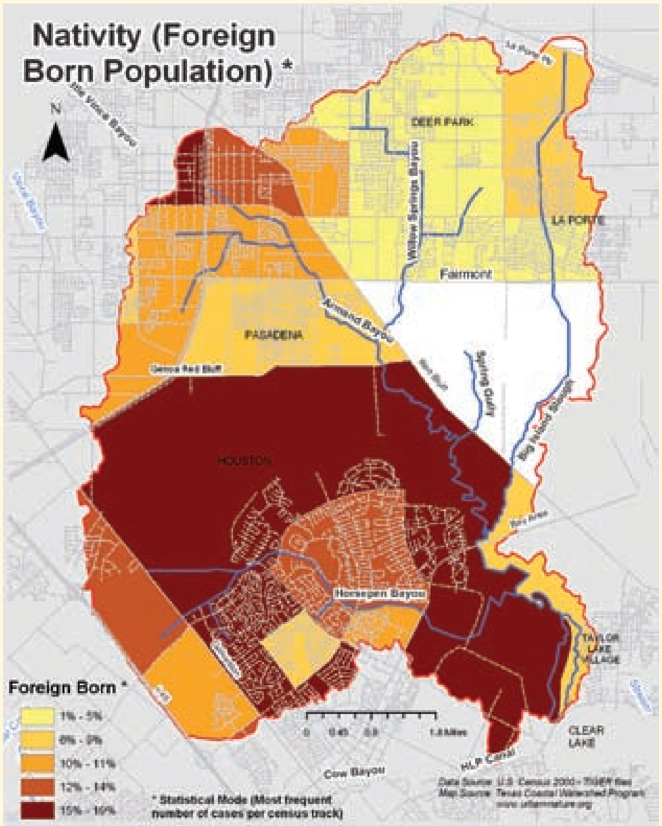
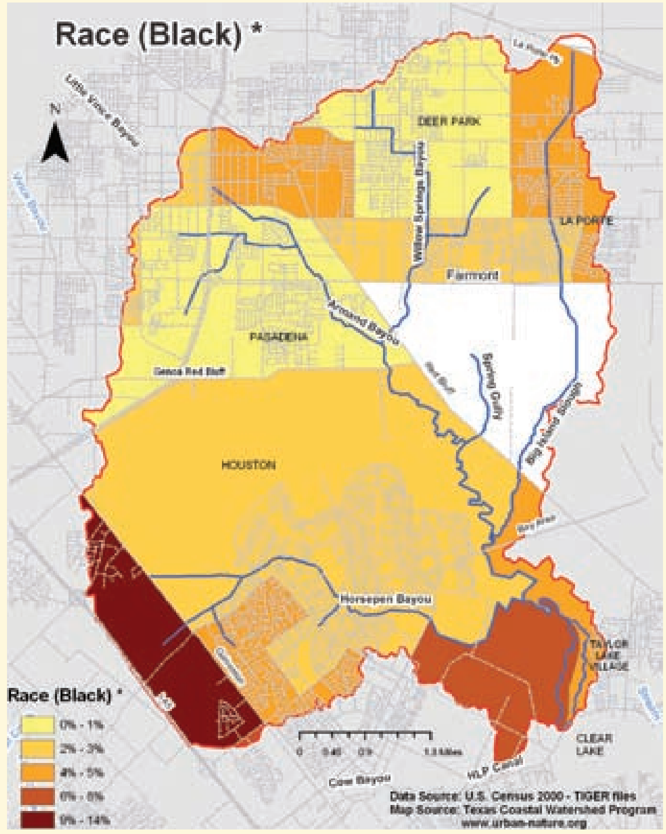
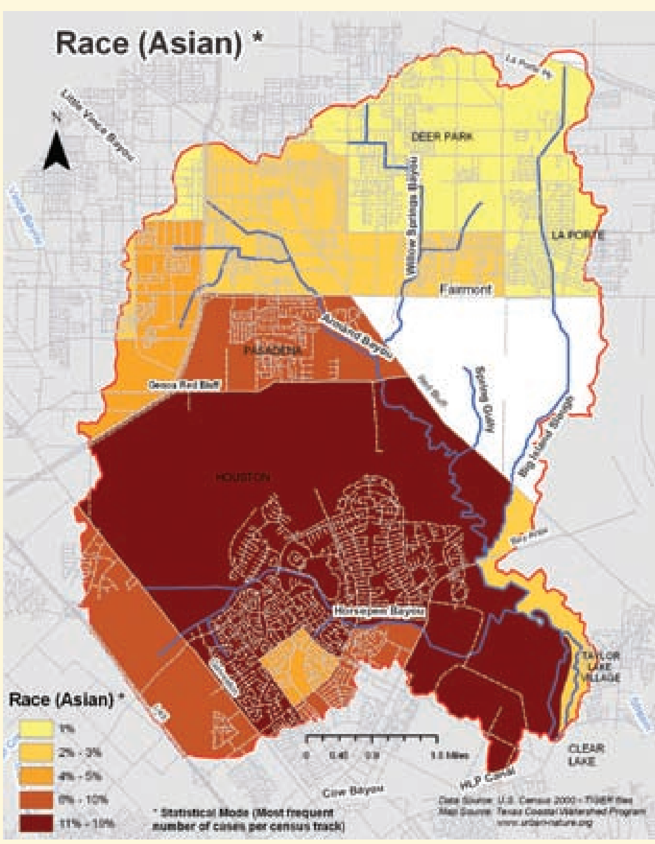


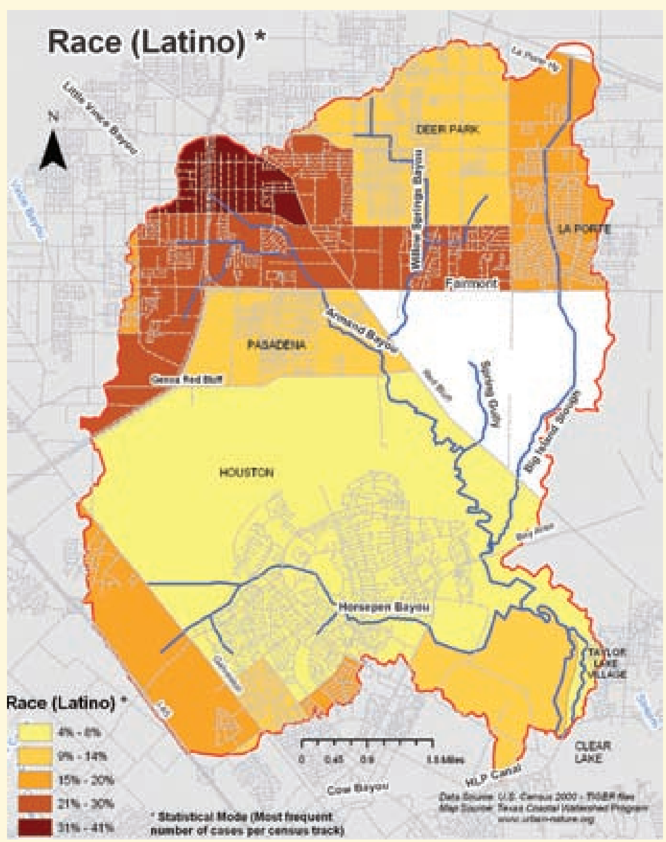
PHOTO © CLIFF MEINHARDT

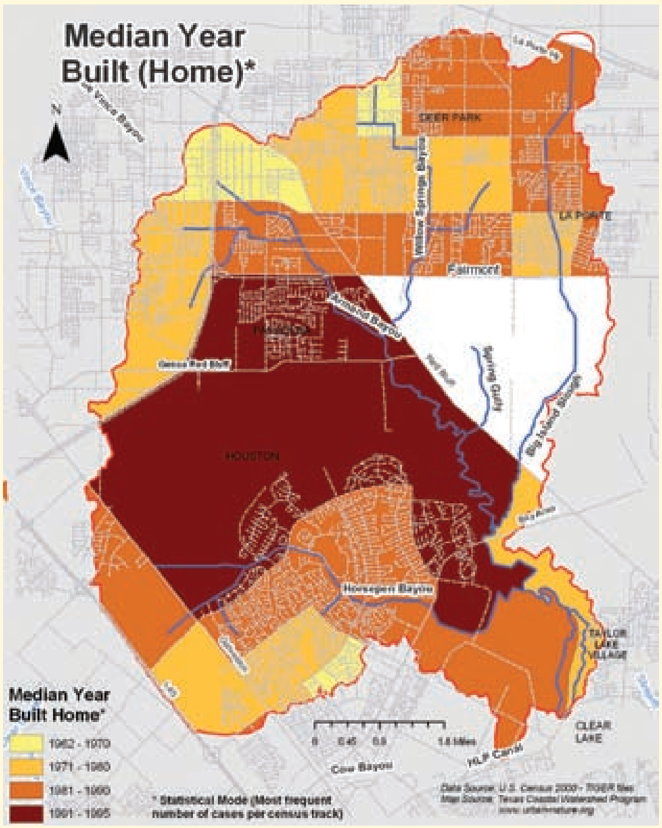
Appendix C. Demographics

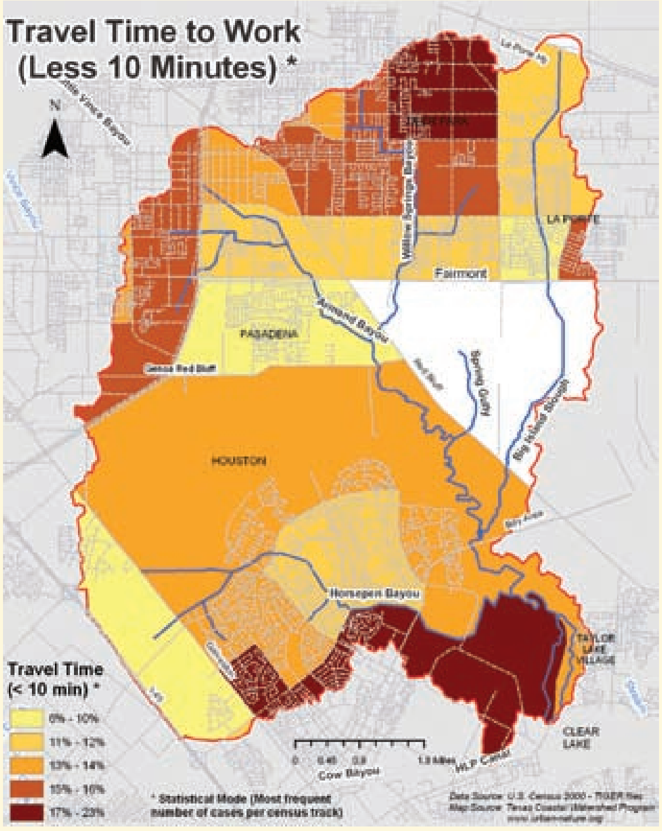


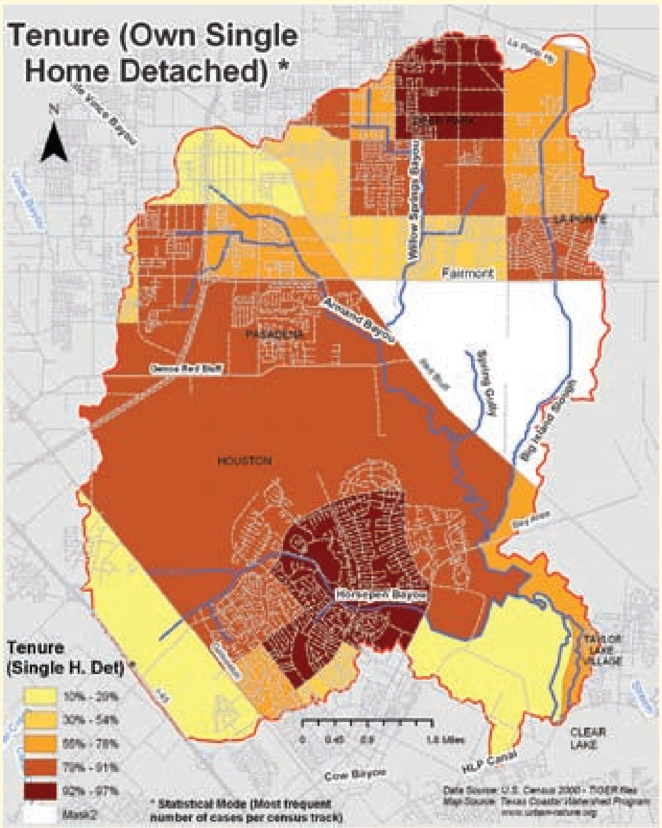







Median Year Built (Home)*
N
DEER PARK
LA PORTE
Fairmont
PASADENA
Armand Bayou
Willow Springs Bayou
Spring Gully
Big Island Slough
Genoa Red Bluff
HOUSTON
Horsepen Bayou
TAYLOR LAKE VILLAGE
CLEAR LAKE
HLP Canal
Cow Bayou
Median Year Built Home*
1962 - 1970
1971 - 1980
1981 - 1990
1991 - 1995
* Statistical Mode (Most frequent number of cases per census track)


Travel Time to Work (Less 10 Minutes) *
N
DEER PARK
LA PORTE
Fairmont
PASADENA
Armand Bayou
Willow Springs Bayou
Spring Gully
Big Island Slough
Genoa Red Bluff
HOUSTON
Horsepen Bayou
TAYLOR LAKE VILLAGE
CLEAR LAKE
HLP Canal
Cow Bayou
Travel Time (< 10 min) *
* Statistical Mode (Most frequent number of cases per census track)


Tenure (Own Single Home Detached) *
N
DEER PARK
LA PORTE
Fairmont
PASADENA
Armand Bayou
Willow Springs Bayou
Spring Gully
Big Island Slough
Genoa Red Bluff
HOUSTON
Horsepen Bayou
TAYLOR LAKE VILLAGE
CLEAR LAKE
HLP Canal
Cow Bayou
Tenure (Single H. Det) *
* Statistical Mode (Most frequent number of cases per census track)

Appendix D. Armand Bayou Watershed Partnership Membership

Latrice Babin	Harris County Pollution Control
Bill Baker	Reliant Energy
Carol Baker	Harris-Galveston Coastal Subsidence District
Charles Bayer	Texas Commission on Environmental Quality
Peter Bowman	University of Houston-Clear Lake
Linda Broach	Texas Commission on Environmental Quality
Joe Broadus	U.S. Geological Survey
Erwin Burden	City of Pasadena
Robert Burgess	Texas Commission on Environmental Quality
David Buzan	Texas Parks and Wildlife Department
James Byrd	Clear Lake City Water Authority
Jim Callan	Shell Oil Company
Del Cannon	Natural Resources Conservation Service
Katie Chimenti	Galveston Bay Conservation and Preservation Assocation
Ben Connelley	City of Deer Park
Cindy Contreras	Texas Parks and Wildlife Department
Jeff DallaRosa	Galveston Bay Estuary Program
Jeanetta Daly	Syngenta (Bayport Industries)
Wendell Daniel	Sam Houston Resource Conservation and Development
Rachel Decker	Harris County Flood Control District
Winston Denton	Texas Parks and Wildlife Department
Helen Drummond	Galveston Bay Estuary Program
Annette Dwyer	Middle Basin Citizens' Representative
Jeff East	U.S. Geological Survey
Alecya Gallaway	University of Houston-Clear Lake
Theo Glanton	City of Houston
Lisa Gonzalez	Houston Advanced Research Center
Myron Hess	National Wildlife Federation
Helen Hodges	SSCI Environmental
Diane Humes	Lower Basin Citizens' Representative
Michael Isermann	City of Pasadena
John Jacob	Texas Coastal Watershed Program
Buddy Jacobs	City of La Porte
Ric Jensen	Texas Water Resources Institute
Daniel Johnson	Pasadena Chamber of Commerce
Ron Jones	U.S. Fish and Wildlife Service
Scott Jones	Galveston Bay Estuary Program
Kathy "KD" Dean	Natural Resources Conservation Service
Larry Koenig	Texas Commission on Environmental Quality
Christine Kolbe	Texas Commission on Environmental Quality
Mark Kramer	Armand Bayou Nature Center
Glen Laird	Harris County Flood Control District
Jim Lester	Houston Advanced Research Center
Ricardo López	Texas Coastal Watershed Program
Jennifer Lorenz	Legacy Land Trust
John Machol	U.S. Army Corps of Engineers
Julie Massey	Texas Marine Advisory Service Galveston County Agent
Carl Masterson	Houston-Galveston Area Council
Robert McCarty	Engineering Consultant, PBS & J
Cathy McCoy	National Association of Conservation Districts
Garry McMahan	Texas General Land Office
Cliff Meinhardt	Legacy Land Trust
Sara Metzger	City of Pasadena
Courtney Miller	Galveston Bay Foundation
Natalie O'Neill	Taylor Lake Village
Randy Palachek	Parsons
Donna Phillips	Texas Commission on Environmental Quality
Patricia Radloff	Texas Parks and Wildlife Department
Suz Rosenberg	Galveston Bay Estuary Program
Gene Rushing	Harris County Flood Control District
Breck Sacra	Reliant Energy
Theron Sage	University of Houston-Clear Lake
Colin Shackelford	Texas Cooperative Extenstion
Linda Shead	The Trust for Public Land
Mona Shoup	Friends of Clear Creek
Andy Sipocz	Texas Parks and Wildlife Department
Gilbert Smith	Harris County Precinct Two
Steve Smith	Texas Commission on Environmental Quality
Steve Speer	City of La Porte
Ralph Taylor	Harris County Flood Control District
Tim Tietjens	City of Pasadena
Bill Toth	Syngenta (Bayport Industries)

Blake Traudt	Texas General Land Office
Raul Villareal	Natural Resources Conservation Service
Michi Vojta	Texas Coastal Watershed Program
Kelly Jo Waldo	Texas Coastal Watershed Program
Brenda Weiser	University of Houston-Clear Lake
Natalie Wiest	Galveston Bay Information Center
Page Williams	Houston Sierra Club
Terry Woodfin	Harris County Flood Control District
Woody Woodrow	Texas Parks and Wildlife Department

Steering Committee of the Armand Bayou Watershed Working Group

Linda Shead	(Committee Chair)	The Trust for Public Land	Non-profit
Michi Vojta	(Facilitator)	Texas Coastal Watershed Program	
James Byrd		Clear Lake City Water Authority	
Ben Connelley		City of Deer Park	
Jeanetta Daly		Bayport Industries (Syngenta)	
Annette Dwyer		Armand Bayou Watershed Citizen Representative	
Theo Glanton		City of Houston	
Diane Humes		Armand Bayou Watershed Citizen Representative	
John Jacob		Texas Coastal Watershed Program	
Daniel Johnson		Pasadena Chamber of Commerce	
Scott Jones		Galveston Bay Estuary Program	Agency
Mark Kramer		Armand Bayou Nature Center	Non-profit
Courtney Miller		Galveston Bay Foundation	Non-profit
Steve Speer		City of La Porte	
Tim Tietjens		City of Pasadena	
Blake Traudt		General Land Office	Agency
Terry Woodfin		Harris County Flood Control District	Agency
Woody Woodrow		Texas Parks & Wildlife Department	Agency

PHOTO BY STEPHAN MYERS

Appendix E. Species Lists

The species lists contained herein are as complete as possible given the information available at the time of writing of this document. Please note that the ABWWG makes no claims that the list is completely comprehensive. When reviewing the species lists, the following should be considered:

1. While the list is large, most of the animals and plants contained in Appendix F have been greatly reduced in abundance and distribution, with individuals now restricted to relatively small land areas,
2. The status of most of the listed species is unknown and the chance for long-term existance of their populations in the Armand Bayou Watershed is unknown, and
3. That many species listed in Appendix F may already have been extirpated from the watershed.

Species of birds observed in the Armand Bayou Watershed and Armand Bayou Coastal Preserve.

Source: Armand Bayou Nature Center staff observations.

Birds	Common Name	Genus Species	Family	Notes
	Anhinga	*Anhinga anhinga*	Anhingidae	
	Ani, Groove-Billed	*Crotophaga sulcirostris*	Cuculidae	
	Bittern, American	*Botaurus lentiginosus*	Ardeidae	
	Bittern, Least	*Ixobrychus exilis*	Ardeidae	
	Blackbird, Brewer's	*Euphagus cyanocephalus*	Icteridae	
	Blackbird, Red-Winged	*Agelaius phoeniceus*	Icteridae	
	Bluebird, Eastern	*Sialia sialis*	Turdidae	
	Bobolink	*Dolichonyx oryzivorus*	Icteridae	
	Bobwhite, Northern	*Colinus virginianus*	Odontophoridae	
	Bunting, Indigo	*Passerina cyanea*	Cardinalidae	
	Bunting, Lark	*Calamospiza melanocorys*	Emberizidae	
	Bunting, Painted	*Passerina ciris*	Cardinalidae	
	Caracara, Crested	*Caracara plancus*	Accipitridae	
	Cardinal, Northern	*Cardinalis cardinalis*	Cardinalidae	
	Catbird, Gray	*Dumetella carolinensis*	Mimidae	
	Chat, Yellow-Breasted	*Icteria virens*	Parulidae	
	Chickadee, Carolina	*Poecile carolinensis*	Paridae	
	Chicken, Attwater's Prairie	*Tympanuchus cupido attwateri*	Phasianidae	Endangered; extirpated from watershed
	Chuck-Will's-Widow	*Caprimulgus carolinesis*	Caprimulgidae	
	Coot, American	*Fulica americana*	Rallidae	
	Cormorant, Double-Crested	*Phalacrocorax auritus*	Phalacrocoracidae	
	Cormorant, Neotropic	*Phalacrocorax brasilianus*	Phalacrocoracidae	
	Cormorant, Olivaceous	*Phalacrocorax olivaceus*	Phalacrocoracidae	
	Cowbird, Brown-Headed	*Molothrus ater*	Icteridae	
	Crane, Sandhill	*Grus canadensis*	Gruidae	
	Creeper, Brown	*Certhia americana*	Certhiidae	
	Crow, American	*Corvus brachyrhynchos*	Corvidae	
	Cuckoo, Black-Billed	*Coccyzus erythropthalmus*	Cuculidae	
	Cuckoo, Yellow-Billed	*Coccyzus americanus*	Cuculidae	
	Dickcissel	*Spiza americana*	Cardinalidae	
	Dove, Common Ground	*Columbina passerina*	Columbidae	

Birds	Common Name	Genus Species	Family	Notes
	Dove, Inca	*Columbina inca*	Columbidae	
	Dove, Mourning	*Zenaida macroura*	Columbidae	
	Dove, Rock	*Columba livia*	Columbidae	
	Dowitcher, Long-Billed	*Limnodromus griseus*	Scolopacidae	
	Duck, Black-Bellied Whistling	*Dendrocynga autumnalis*	Anatidae	
	Duck, Mottled	*Anas fulvigula*	Anatidae	
	Duck, Ruddy	*Oxyura jamaicensis*	Anatidae	
	Duck, Wood	*Aix sponsa*	Anatidae	
	Eagle, Bald	*Haliaeetus leucocephalus*	Accipitriidae	
	Egret, Cattle	*Bubulcus ibis*	Ardeidae	
	Egret, Great	*Ardea alba*	Ardeidae	
	Falcon, Peregrine	*Falco peregrinus*	Falconidae	
	Finch, Purple	*Carpodacus purpureus*	Fringillidae	
	Flicker, Northern	*Colaptes auratus*	Picidae	
	Flycatcher, Acadian	*Empidonax virescens*	Tyrannidae	
	Flycatcher, Great Crested	*Myiarchus crinitus*	Tyrannidae	
	Flycatcher, Least	*Empidonax minimus*	Tyrannidae	
	Flycatcher, Scissor-Tailed	*Tryannus forticatus*	Tyrannidae	
	Flycatcher, Vermillion	*Pyrocephalus rubinus*	Tyrannidae	
	Frigatebird, Magnificent	*Fregata magnificens*	Fregatidae	
	Gallinule, Purple	*Porphyrula martinica*	Rallidae	
	Gnatcatcher, Blue-Gray	*Polioptila caerulea*	Sylviidae	
	Goldeneye, Common	*Bucephala clangula*	Anatidae	
	Goldfinch, American	*Carduelis tristis*	Fringillidae	
	Goose, Canada	*Branta canadensis*	Anatidae	
	Goose, Greater White-Fronted	*Anser albifrons*	Anatidae	
	Goose, Snow	*Chen caerulescens*	Anatidae	
	Grackle, Common	*Quiscalus quiscula*	Icteridae	
	Grackle, Great-Tailed	*Quiscalus mexicanus*	Icteridae	
	Grebe, Eared	*Podiceps nigricollis*	Podicipedidae	
	Grebe, Pied-Billed	*Podilymbus podiceps*	Podicipedidae	
	Grosbeak, Blue	*Guiraca caerulea*	Cardinalidae	
	Grosbeak, Rose-Breasted	*Pheucticus ludovicianus*	Cardinalidae	
	Gull, Herring	*Larus argentatus*	Laridae	
	Gull, Laughing	*Larus atricilla*	Laridae	
	Gull, Ring-Billed	*Larus delawarensis*	Laridae	
	Harrier, Northern	*Circus cyaneus*	Accipitridae	
	Hawk, Broad-Winged	*Buteo platypterus*	Accipitridae	
	Hawk, Common Night-	*Chordeiles minor*	Caprimulgidae	
	Hawk, Cooper's	*Accipiter cooperi*	Accipitridae	
	Hawk, Red-Shouldered	*Buteo lineatus*	Accipitridae	
	Hawk, Red-Tailed	*Buteo jamaicensis*	Accipitridae	
	Hawk, Sharp-Shinned	*Accipiter striatus*	Accipitridae	
	Hawk, Swainson's	*Buteo swainsoni*	Accipitridae	
	Hawk, White-Tailed	*Buteo albicaudatus*	Accipitridae	

Birds	Common Name	Genus Species	Family	Notes
	Heron, Black-Crowned Night-	*Nycticorax nycticorax*	Ardeidae	
	Heron, Great Blue	*Ardea herodias*	Ardeidae	
	Heron, Green	*Butorides virenscens*	Ardeidae	
	Heron, Green-Backed	*Butorides striatus*	Ardeidae	
	Heron, Little Blue	*Egretta caerulea*	Ardeidae	
	Heron, Tricolored	*Egretta tricolor*	Ardeidae	
	Heron, Yellow-Crowned Night-	*Nyctanassa violacea*	Ardeidae	
	Hummingbird, Black-Chinned	*Archilochus alexandri*	Trochilidae	
	Hummingbird, Ruby-Throated	*Archilochus colubris*	Trochilidae	
	Hummingbird, Rufous	*Selasphorus rufus*	Trochilidae	
	Ibis, White	*Eudocimus albus*	Threskiornithidae	
	Ibis, White-Faced	*Plegadis chihi*	Threskiornithidae	
	Jay, Blue	*Cynocitta cristata*	Corvidae	
	Junco, Dark-Eyed	*Junco hyemalis*	Emberizidae	
	Kestrel, American	*Falco spaverius*	Falconidae	
	Killdeer	*Charadrius vociferus*	Charadriiae	
	Kingbird, Eastern	*Tryannus tryannus*	Tyrannidae	
	Kingfisher, Belted	*Ceryle alcyon*	Alcedinidae	
	Kinglet, Golden-Crowned	*Regulus satrapa*	Regulidae	
	Kinglet, Ruby-Crowned	*Regulus calendula*	Regulidae	
	Kite, American Swallow-Tailed	*Elanoides forficatus*	Accipitridae	
	Kite, Black-Shouldered	*Elanus axillaris*	Accipitridae	
	Kite, Mississippi	*Ictinia mississippiensis*	Accipitridae	
	Kite, White-Tailed	*Elanus leucurus*	Accipitridae	
	Loon, Common	*Gavia immer*	Gaviidae	
	Mallard	*Anas platyrhynchos*	Anatidae	
	Martin, Purple	*Progne subis*	Hirundinidae	
	Meadowlark, Eastern	*Sturnella magna*	Icteridae	
	Merganser, Hooded	*Lophodytes cucullatus*	Anatidae	
	Merlin	*Falco columbarius*	Falconidae	
	Mockingbird, Northern	*Mimus polyglottos*	Mimidae	
	Moorhen, Common	*Gallinula chloropus*	Rallidae	
	Nuthatch, Red-Breasted	*Sitta canadensis*	Sittidae	
	Oriole, Baltimore / Northern	*Icterus galbula*	Icteridae	
	Oriole, Orchard	*Icterus spurius*	Icteridae	
	Osprey	*Pandion haliaetus*	Accipitridae	
	Ovenbird	*Seiurus aurocapillus*	Parulidae	
	Owl, Barred	*Strix varia*	Strigidae	
	Owl, Common Barn	*Tyto alba*	Tytonidae	
	Owl, Eastern Screech-	*Otus asio*	Strigidae	
	Owl, Great Horned	*Bubo virginianus*	Strigidae	
	Parula, Northern	*Parula americana*	Parulidae	
	Pelican, American White	*Pelecanus erythrorhynchos*	Pelecanidae	
	Pelican, Brown	*Pelecanus occidentalis*	Pelecanidae	
	Pewee, Eastern Wood- / Eastern	*Contopus virens*	Tyrannidae	

Birds	Common Name	Genus Species	Family	Notes
	Phoebe, Eastern	*Sayornis phoebe*	Tyrannidae	
	Pintail, Northern	*Anas acuta*	Anatidae	
	Pipit, American	*Anthus rubescens*	Motacillidae	
	Pipit, Sprague's	*Anthus spragueii*	Motacillidae	
	Pipit, Water	*Anthus spinoletta*	Motacillidae	
	Rail, Virginia	*Rallus limicola*	Rallidae	
	Redstart, American	*Setophaga ruticilla*	Parulidae	
	Robin, American	*Turdus migratorius*	Turdidae	
	Sandpiper, Least	*Calidris minutilla*	Scolopacidae	
	Sandpiper, Solitary	*Tringa solitaria*	Scolopacidae	
	Sandpiper, Spotted	*Actitus macularia*	Scolopacidae	
	Sandpiper, Western	*Calidris mauri*	Scolopacidae	
	Sapsucker, Yellow-Bellied	*Sphyrapicus varius*	Picidae	
	Scaup, Lesser	*Aythya affinis*	Anatidae	
	Shrike, Loggerhead	*Lanius ludovicianus*	Laniidae	
	Siskin, Pine	*Carduelis pinus*	Fringillidae	
	Snipe, Common	*Gallinago gallinago*	Scolopacidae	
	Snowy Egret	*Egretta thula*	Ardeidae	
	Sora	*Porzana carolina*	Rallidae	
	Sparrow, Chipping	*Spizella passerina*	Emberizidae	
	Sparrow, Field	*Spizella pusilla*	Emberizidae	
	Sparrow, Fox	*Passerella iliaca*	Emberizidae	
	Sparrow, Grasshopper	*Ammodramus savannarum*	Emberizidae	
	Sparrow, Harris's	*Zonotrichia querula*	Emberizidae	
	Sparrow, House	*Passer domesticus*	Passeridae	
	Sparrow, LeConte's	*Ammodramus leconteii*	Emberizidae	
	Sparrow, Lincoln's	*Melospiza lincolnii*	Emberizidae	
	Sparrow, Savannah	*Passerculus sandwichensis*	Emberizidae	
	Sparrow, Song	*Melospiza melodia*	Emberizidae	
	Sparrow, Swamp	*Melospiza georgiana*	Emberizidae	
	Sparrow, Vesper	*Pooecetes gramineus*	Emberizidae	
	Sparrow, White-Crowned	*Zonotrichia leucophrys*	Emberizidae	
	Sparrow, White-Throated	*Zonotrichia albicollis*	Emberizidae	
	Spoonbill, Roseate	*Ajaia ajaja*	Threskiornithidae	
	Starling, European	*Sturnus vulgaris*	Sturnidae	
	Stilt, Black-Necked	*Himantropus mexicanus*	Recurvirostridae	
	Stork, Wood	*Mycteria americana*	Ciconiidae	
	Swallow, Bank	*Riparia riparia*	Hirundinidae	
	Swallow, Barn	*Hirundo rustica*	Hirundinidae	
	Swallow, Cliff	*Petrochelidon pyrrhonota*	Hirundinidae	
	Swallow, Northern Rough-Winged	*Stelgidopteryx serripennis*	Hirundinidae	
	Swallow, Tree	*Tachycineta bicolor*	Hirundinidae	
	Swift, Chimney	*Chaetura pelagica*	Apodidae	
	Tanager, Scarlet	*Piranga olivacea*	Thraupidae	
	Tanager, Summer	*Piranga rubra*	Thraupidae	

Birds	Common Name	Genus Species	Family	Notes
	Teal, Blue-Winged	*Anas discors*	Anatidae	
	Teal, Cinnamon	*Anas cyanoptera*	Anatidae	
	Teal, Green-Winged	*Anas crecca*	Anatidae	
	Tern,	*Sterna foresteri*	Laridae	
	Tern, Caspian	*Sterna caspia*	Laridae	
	Tern, Least	*Sterna antillarum*	Laridae	
	Tern, Royal	*Sterna maxima*	Laridae	
	Thrasher, Brown	*Toxostoma rufum*	Mimidae	
	Thrush, Hermit	*Catharus guttatus*	Turdidae	
	Thrush, Louisiana Water-	*Seiurus motacilla*	Parulidae	
	Thrush, Northern Water-	*Seiurus noveboracensis*	Parulidae	
	Thrush, Swainson's	*Catharus ustulatus*	Turdidae	
	Thrush, Wood	*Hylocichla mustelina*	Turdidae	
	Titmouse, Tufted	*Baeolophus griseus*	Paridae	
	Towhee, Eastern	*Pipilo erythrophthalmus*	Emberizidae	
	Turkey, Eastern Wild	*Meleagis gallopavo silvertris*	Phasianidae	
	Veery	*Catharus fuscescens*	Turdidae	
	Vireo, Blue-Headed / Solitary vireo	*Vireo solitarius*	Vireonidae	
	Vireo, Red-Eyed	*Vireo olivaceus*	Vireonidae	
	Vireo, Warbling	*Vireo gilvus*	Vireonidae	
	Vireo, White-Eyed	*Vireo griseus*	Vireonidae	
	Vireo, Yellow-Throated	*Vireo flavifrons*	Vireonidae	
	Vulture, Black	*Coragyps atratus*	Cathartidae	
	Vulture, Turkey	*Cathartes aura*	Cathartidae	
	Warbler, Bay-Breasted	*Dendroica castanea*	Parulidae	
	Warbler, Black-and-White	*Mniotilta varia*	Parulidae	
	Warbler, Blackburnian	*Dendroica fusca*	Parulidae	
	Warbler, Blackpoll	*Dendroica striata*	Parulidae	
	Warbler, Black-Throated Gray	*Dendroica nigrescens*	Parulidae	
	Warbler, Black-Throated Green	*Dendroica virens*	Parulidae	
	Warbler, Blue-Winged	*Vermivora pinus*	Parulidae	
	Warbler, Canada	*Wilsonia canadensis*	Parulidae	
	Warbler, Cerulean	*Dendroica cerulea*	Parulidae	
	Warbler, Chestnut-Sided	*Dendroica pensylvanica*	Parulidae	
	Warbler, Golden-Winged	*Vermivora chrysoptera*	Parulidae	
	Warbler, Hooded	*Wilsonia citrina*	Parulidae	
	Warbler, Kentucky	*Oporornis formosus*	Parulidae	
	Warbler, Magnolia	*Dendroica magnolia*	Parulidae	
	Warbler, Mourning	*Oporornis philadelphia*	Parulidae	
	Warbler, Nashville	*Vermivora ruficapilla*	Parulidae	
	Warbler, Orange-Crowned	*Vermivora celata*	Parulidae	
	Warbler, Palm	*Dendroica palmarum*	Parulidae	
	Warbler, Pine	*Dendroica pinus*	Parulidae	
	Warbler, Prothonotary	*Protonaria citrea*	Parulidae	
	Warbler, Swainson's	*Limnothlypis swainsonii*	Parulidae	

Birds	Common Name	Genus Species	Family	Notes
	Warbler, Tennessee	*Vermivora peregrina*	Parulidae	
	Warbler, Wilson's	*Wilsonia pusilla*	Parulidae	
	Warbler, Worm-Eating	*Helmitheros vermivorus*	Parulidae	
	Warbler, Yellow	*Dendroica petechia*	Parulidae	
	Warbler, Yellow-Rumped	*Dendroica coronata*	Parulidae	
	Warbler, Yellow-Throated	*Dendroica dominica*	Parulidae	
	Waxwing, Cedar	*Bombycilla cedrorum*	Bombycillidae	
	Whip-Poor-Will	*Caprimulgus vociferus*	Caprimulgidae	
	Willet/Semipalated Snip / Semipalmated Snipe	*Catoptrophorus semipalmatus*	Scolopacine	
	Woodcock, American	*Scolopax minor*	Scolopacidae	
	Woodpecker, Downy	*Picoides pubescen*	Picidae	
	Woodpecker, Hairy	*Picoides villosus*	Picidae	
	Woodpecker, Pileated	*Dryocopus pileatus*	Picidae	
	Woodpecker, Red-Bellied	*Melanerpes carolinus*	Picidae	
	Woodpecker, Red-Headed	*Melanerpes erythrocephalus*	Picidae	
	Wren, Carolina	*Thryothorus ludocicianus*	Troglodytidae	
	Wren, House	*Troglodytes aedon*	Troglodytidae	
	Wren, Marsh	*Cistothorus palustris*	Troglodytidae	
	Wren, Sedge	*Cistothorus platensis*	Troglodytidae	
	Wren, Winter	*Troglodytes troglodytes*	Troglodytidae	
	Yellowlegs, Greater	*Tringa melanoleuca*	Scolopacidae	
	Yellowlegs, Lesser	*Tringa flavipes*	Scolopacidae	
	Yellowthroat, Common	*Geothlypis trichas*	Parulidae	

Species of finfish observed in the Armand Bayou Watershed and Armand Bayou Coastal Preserve.

Source: 1) Armand Bayou Nature Center staff observations; 2) Meyers, Doug. May 1995. *Relative Abundance of Finfishes in the Armand Bayou Coastal Preserve, Texas*. University of Houston-Clear Lake, Masters Thesis.

Finfish	Common Name	Genus Species	Family	Notes
	Anchovy, Bay	*Anchoa mitchilli*	Engraulidae	
	Bass, Largemouth	*Micropterus salmoides*	Centrarchidae	
	Bass, Yellow	*Morone mississippiensis*	Centrarchidae	
	Bluegill / Bluegill Sunfish	*Lepomis macrochirus*	Centrarchidae	
	Bowfin	*Amia calva*	Amiidae	
	Buffalo, Smallmouth	*Ictiobus bubalus*	Catastomidae	
	Bullhead, Black	*Ictalurus melas*	Ictaluridae	
	Bullhead, Yellow	*Ictalurus natalia*	Ictaluridae	
	Carp, Common	*Cyprinus carpio*	Cyprinidae	
	Carp, Grass	*Ctenopharyngodon idella*	Cyprinidae	Non-native, invasive
	Carpsucker, River	*Carpiodes carpio*	Catastomidae	
	Catfish, Blue	*Ictalurus furcatus*	Ictaluridae	
	Catfish, Channel	*Ictalurus punctatus*	Ictaluridae	
	Catfish, Flathead	*Pylodictis olivaris*	Ictaluridae	
	Catfish, Gafftopsail	*Bagre marinus*	Ariidae	
	Catfish, Sea	*Arius felis*	Ariidae	

Finfish	Common Name	Genus Species	Family	Notes
	Chubsucker, Creek	*Erimyzon oblongus*	Catastomidae	
	Crappie, Black	*Pomoxis nigromaculatus*	Centrarchidae	
	Crappie, White	*Pomoxis annularis*	Centrarchidae	
	Croaker, Atlantic	*Micropogonias undulatus*	Sciaenidae	
	Drum, Black	*Pogonias cromis*	Sciaenidae	
	Drum, Freshwater	*Aplodinotus grunniens*	Sciaenidae	
	Drum, Red	*Sciaenops ocellatus*	Sciaenidae	
	Flounder, Southern	*Paralichthys lethostigma*	Bothidae	
	Gar, Alligator	*Lepisosteus spatula*	Lepisosteidae	
	Gar, Longnose	*Lepisosteus osseus*	Lepisosteidae	
	Gar, Shortnosed	*Lepisosteus platostomus*	Lepisosteidae	
	Gar, Spotted	*Lepisosteus oculatus*	Lepisosteidae	
	Goby, Clown	*Microgobius gulosus*	Gobiidae	
	Goby, Naked	*Gobiosoma bosc*	Gobiidae	
	Goby, Violet	*Gobioides broussonetti*	Gobiidae	
	Hogchoker	*Trinectes maculatus*	Soleidae	
	Killifish, Bayou	*Fundulus pulverous*	Cyprinodontidae	
	Killifish, Diamond	*Adinia xenica*	Fundulidae	
	Killifish, Gulf	*Fundulus grandis*	Cyprinodontidae	
	Killifish, Rainwater	*Lucania parva*	Cyprinodontidae	
	Ladyfish	*Elops saurus*	Elopidae	
	Leatherjack	*Oligoplites saurus*	Carangidae	
	Menhaden, Gulf	*Brevoortia patronus*	Clupeidae	
	Minnow, Sheepshead	*Cyprinodon variegatus*	Cyprinodontidae	
	Molly, Sailfin	*Poecilia latipinna*	Poeciliidae	
	Mosquitofish	*Gambusia affinis*	Poecilidae	
	Mullet, Striped	*Mugil cephalus*	Mugilidae	
	Mullet, White	*Mugil curema*	Mugilidae	
	Pinfish	*Lagodon rhomboides*	Sparidae	
	Pipefish, Gulf	*Syngnathus scovelli*	Synganthidae	
	Puffer, Southern	*Sphoeroides nephelus*	Tetraodontidae	
	Redhorse, Blacktail	*Moxostoma poecilurum*	Catastomidae	
	Runner, Blue	*Caranx crysos*	Carangidae	
	Searobin, Bighead	*Prionotus tribulus*	Triglidae	
	Seatrout, Sand	*Cynoscion arenarius*	Sciaenidae	
	Seatrout, Spotted / Speckled	*Cynoscion nebulosus*	Sciaenidae	
	Shad, Gizzard	*Dorosoma cepedianum*	Clupeidae	
	Shad, Threadfin	*Dorosoma petenense*	Clupeidae	
	Sheepshead	*Archosargus probactocephalus*	Sparidae	
	Shiner, Golden	*Notemigonus crysoleucas*	Cyprinidae	
	Silversides, Inland	*Menidia beryllina*	Atherinidae	
	Silversides, Tidewater	*Menidia peninsulae*	Atherinidae	
	Sole, Lined	*Achirus lineatus*	Achiridae	
	Spot	*Leiostomus xanthurus*	Sciaenidae	
	Sunfish, Dollar	*Lepomis marginatus*	Centrarchidae	

Finfish	Common Name	Genus Species	Family	Notes
	Sunfish, Green	*Lepomis cyanellus*	Centrarchidae	
	Sunfish, Longear	*Lepomis megalotis*	Centrarchidae	
	Sunfish, Orangespotted	*Lepomis humilis*	Centrarchidae	
	Sunfish, Redear	*Lepomis microlophus*	Centrarchidae	
	Tonguefish, Blackcheek	*Symphurus plagiusa*	Cynoglossidae	
	Warmouth	*Lepomis gulosus*	Centrarchidae	
	Whiff, Bay	*Citharichthys spilopterus*	Bothidae	

Species of herptofauna observed in the Armand Bayou Watershed and Armand Bayou Coastal Preserve.
Source: Armand Bayou Nature Center staff observations.

Herptofauna				
	Alligator, American	*Alligator mississippiensis*	Crocodylidae	
	Amphiuma, Three-toed	*Amphiuma tridactylum*	Amphiumidae	
	Anole, Green	*Anolis carolinensis*	Iguanidae	
	Coachwhip, Eastern	*Masticophis flagellum*	Colubridae	
	Cooter, Texas	*Pseudemys texana*	Emydidae	
	Copperhead, Southern	*Agkistrodon contortix*	Viperidae	
	Cottonmouth, Western	*Agkistrodon piscivorus*	Viperidae	
	Frog, Blanchard's Cricket	*Acris crepitans creptians*	Hylidae	
	Frog, Bull-	*Rana catesbeiana*	Ranidae	
	Frog, Cope's Gray Tree-	*Hyla chrysoscelis*	Hylidae	
	Frog, Cricket	*Acris crepitans*	Hylidae	
	Frog, Gray Tree-	*Hyla versicolor*	Hylidae	
	Frog, Green Tree-	*Hyla cinerea*	Hylidae	
	Frog, Leopard	*Rana sphenocephala*	Ranidae	
	Frog, Sheep	*Hypopachus variolosus*	Microhylidae	
	Frog, Squirrel Tree-	*Hyla squirella*	Hylidae	
	Frog, Upland Chorus	*Pseudacris triseriata feriarum*	Hylidae	
	Gekko, Mediterranean	*Hemidactylus turcicus*	Gekkonidae	Non-native
	Lizard, Texas Horned	*Phrynosoma cornutum*	Iguanidae	Extirpated from watershed; federally C2 / threatened in Texas
	Lizard, Western Slender Glass	*Ophisaurus attenuatus attenuatus*	Anguidae	
	Peeper, Northern Spring	*Pseudacris crucifer crucifer*	Hylidae	
	Racer, Eastern Yellow-Bellied	*Coluber constrictor*	Colubridae	
	Salamander, Smallmouth	*Ambystoma texanum*	Ambystomatidae	
	Siren, Western Lesser	*Siren intermedia nettingi*	Sirenidae	
	Skink, Broadhead	*Eumeces laticeps*	Scincidae	
	Skink, Five-Lined	*Eumeces fasciatus*	Scincidae	
	Skink, Ground	*Scincella lateras*	Scincidae	
	Slider, Red-eared	*Chysemys scripta elegans*	Emydidae	
	Snake, Blotched Water	*Nerodia erythrogaster transversa*	Colubridae	
	Snake, Broad-banded Water	*Nerodia fasciata confluens*	Colubridae	
	Snake, Diamondback Water	*Nerodia rhombifer rhombifer*	Colubridae	
	Snake, Eastern Hognose	*Heterdon platyrhinos*	Colubridae	

Herptofauna	Common Name	Genus Species	Family	Notes
	Snake, Flathead	*Tantilla gracilis*	Colubridae	
	Snake, Graham's Crayfish	*Regina grahamii*	Colubridae	
	Snake, Great Plains Rat	*Elaphe guttata emoryi*	Colubridae	
	Snake, Marsh Brown	*Storeria dekayi limnetes*	Colubridae	
	Snake, Prairie King-	*Lampropeltis calligaster*	Colubridae	
	Snake, Rough Earth	*Virginia striatula*	Colubridae	
	Snake, Rough Green	*Ophyodrys aestivus*	Colubridae	
	Snake, Speckled King-	*Lampropeltis getulus*	Colubridae	
	Snake, Texas Brown	*Storeria dekayi texana*	Colubridae	
	Snake, Texas Coral	*Micrurus fulvius*	Elapidae	
	Snake, Texas Rat	*Elaphe obsoleta*	Colubridae	
	Snake, Western Mud	*Farancia abacura reinwardtii*	Colubridae	
	Snake, Western Pygmy Rattle-	*Sistrurus miliarus*	Viperidae	
	Snake, Western Ribbon	*Thamnophis proximus proximus*	Colubridae	
	Snake, Yellowbelly Water	*Nerodia erythrogaster favigaster*	Colubridae	
	Softshell, Pallid Spiny	*Trionyx spiniferus pallidus*	Trionychidae	
	Toad, Eastern Narrow-Mouth	*Gastrophryne carolinensis*	Microhylidae	
	Toad, Gulf Coast	*Bufo valliceps vaiilcpes*	Bufonidae	
	Turtle, Alligator Snapping	*Macroclemys temminckii*	Chelydridae	
	Turtle, Common Musk	*Sternotherus odoratus*	Kinosternidae	
	Turtle, Common Snapping	*Chelydra serpentina serpentina*	Chelydridae	
	Turtle, Mississippi Mud	*Kinosternon subrubrum hippocrepis*	Kinosternidae	
	Turtle, Ornate Box	*Terrapene ornata ornata*	Emydidae	
	Turtle, Three-Toed Box	*Terrapene carolina triunguis*	Emydidae	
	Turtle, Western Chicken	*Deirochelys reticularia miaria*	Emydidae	
	Waterdog, Gulf Coast	*Necturus beyeri*	Proteidae	

Species of mammals with known ranges in the Armand Bayou Watershed and Armand Bayou Coastal Preserve.

Source: Davis, William B. and David J. Schmidly. 1994. The Mammals of Texas. Texas Parks & Wildlife Press, Austin, Texas.

Mammals	Common Name	Genus Species	Family	Notes
	Armadillo, Nine Banded	*Dasypus novemcinctus*	Dasypodidae	
	Bat, Big Brown	*Eptesicus fuscus*	Phyllostomidae	
	Bat, Big Free-Tailed	*Nyctinomops macrotis*	Molossidae	
	Bat, Brazilian Free-tailed	*Tadarida brasiliensis*	Molossidae	
	Bat, Evening	*Nycticeius humeralis*	Vespertilionidae	
	Bat, Hoary	*Lasiurus cinereus*	Vespertilionidae	
	Bat, Northern Yellow	*Lasiurus intermedius*	Vespertilionidae	
	Bat, Seminole	*Lasiurus seminolus*	Vespertilionidae	
	Bat, Silver-Haired	*Lasionycteris noctivagans*	Vespertilionidae	
	Bear, Black	*Ursus americanus*	Ursidae	Endangered in Texas; proposed to be listed in federal register as Threatened. – Now extinct in Texas except for remnant populations in the Trans Pecos

Mammals	Common Name	*Genus Species*	Family	Notes
	Beaver, American	*Castor Canadensis*	Castoridae	May be extirpated from watershed
	Bison	*Bos bison*	Bovidae	Now extinct in the wild in Texas
	Bobcat	*Lynx rufus*	Felidae	
	Cattle (wild)	*Bos taurus*	Bovidae	Non-native; (had) escaped from introduced populations
	Cougar / Mountain Lion / Puma	*Felis concolor*	Felidae	Now gone from much of the range except south Texas and the Trans Pecos
	Coyote	*Canis latrans*	Canidae	
	Deer Mouse	*Peromyscus maniculatus*	Muridae	
	Deer, White-Tailed	*Odocoileus virginianus*	Cervinae	
	Fox, Red	*Vulpes fulva*	Canidae	Non-native; Introduced in eastern and central parts of Texas
	Gopher, Baird's Pocket	*Geomys breviceps*	Geomyidae	
	Hog, Feral / Pig	*Sus scrofa*	Suidae	Non-native; escaped from introduced populations; invasive
	Horse, (Wild)	*Equus caballus*	Equidae	Non-native; escaped from introduced populations; extirpated from the watershed
	Jackrabbit, Black-Tailed	*Lepus californicus*	Leporidae	May be extirpated from watershed
	Jaguar	*Panthera onca*	Felidae	Now extinct in Texas
	Mink	*Mustela vison*	Mustelidae	
	Mole, Eastern	*Scalopus aquaticus*	Talpidae	
	Mouse, Eastern Harvest	*Reithrodontomys humulis*	Muridae	
	Mouse, Fulous Harvest	*Reithrodontomys fulvescens*	Muridae	
	Mouse, Hispid Pocket	*Chaetodipus hispidus*	Heteromyidae	
	Mouse, House	*Mus musculus*	Muridae	Non-native
	Mouse, Northern Pymgy	*Baiomys taylori*	Muridae	
	Mouse, White-Footed	*Peromyscus leucopus*	Cricetidae	
	Muskrat, Common	*Ondatra zibethicus*	Muridae	
	Myotis, Southeastern	*Myotis austroriparius*	Vespertilionidae	Threatened; listed in federal register as Category 2 species
	Nutria / Coypu	*Myocaster coypus*	Myocastoridae	Non-native, invasive
	Ocelot	*Felis pardalis*	Felidae	Extirpated from watershed
	Opossum	*Didelphis marsupialis*	Didelphidae	
	Opossum, Virginia	*Didelphis virginiana*	Didelphidae	
	Otter, River	*Lutra canadensis*	Mustelidae	

Mammals	Common Name	*Genus Species*	Family	Notes
	Pipistrelle, Eastern	*Pipistrellus subflavus*	Vespertilionidae	
	Rabbit, Eastern Cottontail	*Sylvilagus floridanus*	Leporidae	
	Rabbit, Swamp	*Sylvilagus aquaticus*	Leporidae	
	Raccoon	*Procyon lotor*	Procyonidae	
	Rat, Hispid Cotton	*Sigmodon hispidus*	Cricetidae	
	Rat, Marsh Rice	*Oryzomys palustris*	Muridae	
	Rat, Norway / Brown	*Rattus norvegicus*	Muridae	
	Shrew, Least	*Cryptotis parva*	Soricidae	
	Shrew, Southern Short-Tailed	*Blarina brevicauda*	Soricidae	
	Skunk, Eastern Spotted	*Spilogale putorius*	Mustelidae	
	Skunk, Striped	*Mephitis mehitis*	Mustelidae	
	Squirrel, Eastern Flying	*Glaucomys volans*	Anomaluridae	
	Squirrel, Eastern Fox	*Sciurus niger*	Sciuridae	
	Squirrel, Eastern Gray	*Sciurus carolinensis*	Sciuridae	
	Squirrel, Thirteen-Lined Ground	*Didelphidae*	Sciuridae	May be extirpated from watershed
	Weasel, Long-Tailed	*Mustela frenata*	Mustelidae	May be extirpated from watershed
	Wolf, Gray	*Canis lupus*	Canidae	Now extinct in Texas
	Wolf, Red	*Canis rufus*	Canidae	Endangered; now extinct in Texas
	Woodrat, Eastern	*Neotoma floridana*	Murida	

Species of plants observed in the Armand Bayou Watershed and Armand Bayou Coastal Preserve.

Source: 1) Armand Bayou Nature Center (ABNC) staff observations; 2) Brown, Larry E. January 2001. A Plant Checklist of a Harris County Flood Control Detention Basin. 3) Oliver, Mary E. Prairie and forest vegetation of the Armand Bayou Nature Center, Harris County, Texas. University of Houston-Clear Lake, Masters Thesis

Plants	Common Name	Genus Species	Family	Notes
	Agalinis, Prairie/Rough	*Agalinis heterophylla*	Scrophulariaceae	ABNC observation
	Agalinis, Rough	*Agalinis fasiculata*	Scrophulariaceae	ABNC observation
	Aloe, False	*Manfreda virginica*	Amaryllidaceae	Brown (2001)
	Amaranth, Water	*Amaranthus rudis*	Amaranthaceae	Brown (2001)
	Antelope Horn / Green Milkweed	*Asclepias viridis*	Asclepiadaceae	Brown (2001)
	Arrowhead	*Sagittaria papillosa*	Alismataceae	Brown (2001)
	Arrowhead	*Sagittaria platyphylla*	Alismataceae	Brown (2001)
	Arrowhead / Bulltongue	*Sagittaria lancifolia*	Alismataceae	ABNC observation
	Arrowroot, Grassy / Duck Potato	*Sagittaria graminea*	Alismataceae	ABNC observation
	Arrowwood	*Virbunum dentatum*	Caprifoliaceae	ABNC observation
	Ash, Green	*Fraxinus pennsylvanica*	Oleaceae	ABNC observation
	Ash, White	*Fraxinus americana*	Oleaceae	ABNC observation
	Aster, Bushy	*Aster dumosus*	Asteraceae	ABNC observation
	Aster, Calico/White Woodland	*Aster lateriflorus*	Asteraceae	ABNC observation
	Aster, Low	*Helastrum hemisphericum*	Asteraceae	ABNC observation
	Aster, Soft Golden-	*Chrysopsis pilosa*	Asteraceae	Brown (2001)
	Aster, White Prairie	*Aster ericoides*	Asteraceae	Brown (2001)
	Barley, Little	*Hordeum pusillum*	Poaceae	Brown (2001)

Plants	Common Name	Genus Species	Family	Notes
	Basket Flower	*Centauria americana*	Asteraceae	ABNC observation
	Basswood	*Tilia caroliniana*	Tiliaceae	ABNC observation
	Beakrush	*Rhynchospora harveyi*	Cyperaceae	Brown (2001)
	Beakrush, Anglestem	*Rhynchospora caduca*	Cyperaceae	ABNC observation
	Beakrush, Globe	*Rhynchospora globularis*	Cyperaceae	ABNC observation
	Beakrush, Horned	*Rhynchospora corniculata*	Cyperaceae	ABNC observation
	Bean, Coffee	*Sesbania exaltata*	Fabaceae	Brown (2001)
	Bean, Coral	*Eythrina herbacea*	Fabaceae	ABNC observation
	Bean, Trailing Wild-	*Strophostyles helvula*	Fabaceae	Brown (2001)
	Beauty-Berry, American	*Callicarpa americana*	Verbenaceae	ABNC observation
	Bedstraw	*Galium aparine*	Roseaceae	Brown (2001)
	Bedstraw, Bluntleaf	*Galium obtusum*	Roseaceae	Brown (2001)
	Bedstraw, Marsh/Dye	*Galium tinctorium*	Rubiaceae	ABNC observation
	Bedstraw, Southwestern	*Galium virgatum*	Roseaceae	Brown (2001)
	Beebalm, Lemon	*Monarda citriodora*	Lamiacieae	ABNC observation
	Bentgrass, Winter	*Agrostis hyemalis*	Poaceae	Brown (2001)
	Berry, Black-	*Rubus argutus*	Roseaceae	Brown (2001)
	Berry, Farkle-	*Vaccinium arboreum*	Ericaceae	ABNC observation
	Berry, Louisiana Dew-	*Rubus louisianus*	Rosaceae	ABNC observation
	Berry, Southern Dew-	*Rubus trivialis*	Rosaceae	ABNC observation
	Birch, River	*Betula nigra*	Betulaceae	ABNC observation
	Black Medic	*Medicago lupulina*	Fabaceae	Brown (2001); non-native
	Black-Eyed Susan	*Rudbeckia hirta*	Asteraceae	ABNC observation
	Bladderpod	*Sesbania vesicaria*	Fabaceae	Brown (2001)
	Blanketflower, Lanceleaf	*Gaillardia aestivalis*	Asteraceae	Brown (2001)
	Blazing Star / (Kansas) Gayfeather	*Liatris pycnostachya*	Asteraceae	ABNC observation
	Blazing Star, Slender / Sharp Gayfeather	*Liatris acidota*	Asteraceae	ABNC observation
	Blue Star	*Amsonia tabernaemontana*	Apocynaceae	Brown (2001)
	Bluehearts	*Buchnera americana*	Scrophulariaceae	Brown (2001)
	Blue-Star	*Amsonia glaberrima*	Apcynaceae	ABNC observation
	Bluestem, Angleton	*Dichanthium aristatum*	Poaceae	Brown (2001); Non-native
	Bluestem, Awnless/ Awnless Beardgrass	*Bothriochloa exaristata*	Poaceae	ABNC observation
	Bluestem, Big	*Andropogon gerardii*	Poaceae	ABNC observation
	Bluestem, Broomsedge	*Andropogon virginicus*	Poaceae	ABNC observation
	Bluestem, Bushy	*Andropogon glomeratus*	Poaceae	ABNC observation
	Bluestem, King Ranch	*Bothriochloa ischaemum var. songarica*	Poaceae	Brown (2001); Non-native
	Bluestem, Kleberg	*Dichanthium annulatum*	Poaceae	Brown (2001); Non-native
	Bluestem, Little	*Schizachyrium scoparium*	Poaceae	ABNC observation
	Bluestem, Silver	*Bothriochloa laguroides*	Poaceae	Brown (2001)
	Bluets	*Hedyotis nigricans*	Rubiaceae	ABNC observation
	Boltonia, White	*Boltonia asteroides*	Asteraceae	ABNC observation
	Briar, Sensitive	*Schrankia hystricina*	Fabaceae	ABNC observation; Syn. *Mimosa quadrivalvis* var. *hystricina*

Plants	Common Name	Genus Species	Family	Notes
	Brome, Rye	*Bromus secalinus*	Poaceae	Brown (2001)
	Buckthorn, Carolina	*Rhamnus caroliniana*	Rhamnaceae	ABNC observation
	Bulrush, California	*Scirpus californicus*	Cyperaceae	ABNC observation
	Bundleflower	*Desmanthus virgatus*	Fabaceae	Brown (2001)
	Bundleflower, Upright	*Desmanthus illinoensis*	Fabaceae	Brown (2001)
	Bur, Grass	*Cenchrus spinifex*	Poaceae	Brown (2001)
	Buttercup, Carolina	*Ranunculus carolinianus*	Ranunculaceae	ABNC observation
	Butterweed	*Senecio tampicanus*	Asteraceae	Brown (2001)
	Button-Bush	*Cephalanthus occidentalis*	Rosaceae	ABNC observation
	Cat's Ear	*Hypochaeris microcephala*	Asteraceae	Brown (2001); Non-native
	Cattail	*Typha domingensis*	Typhaceae	Brown (2001)
	Cattail	*Typha latifolia*	Typhaceae	Brown (2001)
	Cedar, (Eastern) Red	*Juniperus virginiana*	Cupressaceae	ABNC observation
	Celery, Wild	*Apium leptophyllum*	Apiaceae	Non-native
	Centaury, Branched	*Centaurium pulchellum*	Gentianaceae	Brown (2001)
	Cherry, False Jerusalem	*Solanum capsicastrum*	Solanaceae	ABNC observation
	Cherry, Ground-	*Physalis cinerascens*	Solanaceae	Brown (2001)
	Chervil	*Chaerophyllum tainturieri*	Apiaceae	Brown (2001)
	Clover, Bur	*Medicago polymorpha*	Fabaceae	Brown (2001); non-native
	Clover, Crimson	*Trifolium incarnatum*	Fabaceae	Brown (2001); Non-native
	Clover, Littleleaf Tick-	*Desmodium ciliare*	Fabaceae	Brown (2001)
	Clover, Persian	*Trifolium resupinatum*	Fabaceae	Brown (2001); Non-native
	Clover, Red	*Trifolium pratense*	Fabaceae	Brown (2001); Non-native
	Clover, White	*Trifolium repens*	Fabaceae	Brown (2001); Non-native
	Clover, White Prairie	*Dalea candida*	Fabaceae	Brown (2001)
	Clover, White Sweet	*Melilotus alba*	Fabaceae	Brown (2001); non-native
	`Clover, Yellow Sweet	*Melilotus indicus*	Fabaceae	Brown (2001); non-native
	Coneflower, Shiny	*Rudbeckia nitida*	Asteraceae	ABNC observation
	Coneflower, Shiny Leaf	*Rudbeckia texana*	Asteraceae	Brown (2001)
	Copperleaf, Slender	*Acalypha gracilens*	Euphorbiaceae	ABNC observation
	Cordgrass, Gulf / Sacahuista	*Spartina spartinae*	Poaceae	ABNC observation
	Cordgrass, Marshhay	*Spartina patens*	Poaceae	ABNC observation
	Cordgrass, Prairie	*Spartina pectinata*	Poaceae	ABNC observation
	Cordgrass, Smooth	*Spartina alterniflora*	Poaceae	ABNC observation
	Corn Salad	*Valerianella woodsiana*	Valerianaceae	Brown (2001)
	Cottonwood	*Populus deltoides*	Salicaceae	Brown (2001)
	Creeper, Trumpet	*Campsis radicans*	Bignoniaceae	ABNC observation
	Creeper, Virginia	*Parthenocissus quinquefolia*	Vitaceae	ABNC observation
	Croton, False-	*Caperonia palustris*	Euphorbiaceae	Brown (2001)
	Croton, One-Seeded	*Croton monanthogynus*	Euphorbiaceae	Brown (2001)
	Crowfoot, Common	*Ranunculus sardous*	Ranunculaceae	Brown (2001); non-native
	Cypress, Bald	*Taxodium distichum*	Taxodiaceae	ABNC observation
	Daisy, Sea-Ox-Eye	*Borrichia frutescens*	Asteraceae	ABNC observation
	Daisy, Smallhead Doll's-	*Boltonia diffusa*	Asteraceae	Brown (2001)

Plants	Common Name	Genus Species	Family	Notes
	Daisy, Stagger	*Calyptocarpus vialis*	Asteraceae	Brown (2001)
	Dandelion, Dwarf	*Krigia cespitosa*	Asteraceae	Brown (2001)
	Dandelion, False	*Pyrrhopappus pauciflorus*	Asteraceae	Brown (2001): Syn. *Pyrrhopappus multicaulis*
	Dandelion, False	*Pyrrhopappus carolinianus*	Asteraceae	ABNC observation
	Dayflower, Erect	*Commelina erecta*	Commelinaceae	ABNC observation
	Dichanthelium, Scribner's	*Dichanthelium oligosanthes*	Poaceae	ABNC observation
	Dichanthelium, Variable	*Dichanthelium sp. (broadleaf)*	Poaceae	ABNC observation
	Dichanthelium, Variable	*Dichanthelium commutatum*	Poaceae	ABNC observation
	Dichanthelium, Wooly	*Dichanthelium acuminatum*	Poaceae	ABNC observation
	Dock, Curly-Leaf	*Rumex crispus*	Polygonaceae	ABNC observation; non-native
	Dock, Fiddle	*Rumex pulcher*	Polygonaceae	Brown (2001); Non-native
	Dock, Mexican	*Rumex chrysocarpus*	Polygonaceae	Brown (2001)
	Dodder, Showy	*Cuscuta indecora*	Cuscutaceae	ABNC observation
	Dogbane, Climbing	*Trachelospermum difforme*	Apocynaceae	Brown (2001)
	Dogshade, Finger	*Cynoscidium digitatum*	Apiaceae	Brown (2001)
	Dogwood, Rough-Leaved	*Cornus drummondii*	Corneaceae	Brown (2001)
	Dropseed, Hidden	*Sporobulus compositus*	Poaceae	Brown (2001)
	Dropseed, Tall	*Sporobolus asper*	Poaceae	ABNC observation
	Duckweed	*Lemna polyrhiza*	Lemnaceae	ABNC observation
	Elderberry	*Sambucus canadensis*	Caprifoliaceae	Brown (2001)
	Elephant Ear	*Colocasia esculenta*	Araceae	ABNC observation; non-native; invasive
	Elm, American	*Ulmus americana*	Ulmaceae	ABNC observation
	Elm, Cedar	*Ulmus crassifolia*	Ulmaceae	ABNC observation
	Elm, Winged	*Ulmus alata*	Ulmaceae	ABNC observation
	Eryngo, Hooker	*Eryngium hookeri*	Apiaceae	ABNC observation
	Eupatorium, Mohr's	*Eupatorium mohrii*	Asteraceae	ABNC observation
	Evolvulus, Silky	*Evolvulus sericeus*	Convolvulaceae	ABNC observation
	Eyebane	*Euphorbia nutans*	Euphorbiaceae	Brown (2001)
	False Goldenrod / Euthamia	*Euthamia leptocephala*	Asteraceae	ABNC observation
	Fennel, Dog	*Eupatorium capillifolium*	Asteraceae	ABNC observation
	Fern, Resurrection	*Pleopeltis polypodioides*	Polypodiaceae	ABNC observation
	Fescue, Tall	*Festuca arundinacea*	Poaceae	Brown (2001); Non-native
	Feverfew	*Parthenium hysterophorus*	Asteraceae	Brown (2001)
	Fimbry, Hairy / Common	*Fimbristylis puberula*	Cyperaceae	ABNC observation
	Flatsedge, Buttonbush	*Cyperus cephalanthus*	Cyperaceae	Brown (2001)
	Flatsedge, Fragrant /Large-Head	*Cyperus odoratus*	Cyperaceae	Brown (2001)
	Flatsedge, Green	*Cyperaceae virens*	Cyperaceae	ABNC observation
	Flatsedge, Pond	*Cyperus ochraceus*	Cyperaceae	Brown (2001); non-native
	Flatsedge, Sheadhead	*Cyperus haspan*	Cyperaceae	Brown (2001)
	Flatsedge, Sticky	*Cyperus elegans*	Cyperaceae	Brown (2001)
	Flatsedge, Tall	*Cyperus eragrostis*	Cyperaceae	Brown (2001); non-native

Plants	Common Name	Genus Species	Family	Notes
	Flatsedge, Taperleaf	*Cyperus acuminatus*	Cyperaceae	Brown (2001)
	Flax	*Limun berlandieri*	Linaceae	Brown (2001)
	Flax, Sucker	*Linum medium*	Linaceae	ABNC observation
	Fleabane, Philadelphia	*Erigeron philadelphicus*	Asteraceae	ABNC observation
	Fringe Tree	*Chionanthus virginicus*	Oleaceae	ABNC observation
	Frogfruit	*Phyla lanceolata*	Verbenaceae	Brown (2001)
	Frogfruit	*Phyla nodiflora*	Verbenaceae	Brown (2001)
	Garlic, False / False Onion	*Nothoscordum bivalve*	Liliaceae	ABNC observation
	Gaura, Tall/Biennial	*Gaura longiflora*	Onagraceae	ABNC observation
	Gaura, White/Prairie	*Gaura lindheimeri*	Onagraceae	ABNC observation
	Geranium	*Geranium carolinianum*	Geraniaceae	Brown (2001)
	Germander, Coastal	*Teucrium cubense*	Lamiacieae	Brown (2001)
	Goldenrod	*Solidago altissima*	Asteraceae	ABNC observation
	Goldenrod, Common	*Solidago candensis*	Asteraceae	ABNC observation
	Goldenrod, False / Texas Goldentop	*Euthamia gymnospermoides*	Asteraceae	Syn. Euthamia pulverulenta
	Goldenrod, Seaside	*Solidago sempervirens*	Asteraceae	ABNC observation
	Goldenrod, Seaside	*Solidago stricta*	Asteraceae	ABNC observation
	Goldenrod, Twistleaf	*Solidago tortifolia*	Asteraceae	ABNC observation
	Goldenwave / Plains Coreopsis	*Coreopsis tinctoria*	Asteraceae	ABNC observation
	Grama, Sideoats	*Bouteloua curtipendula*	Poaceae	Brown (2001)
	Grape, Muscadine	*Vitis rotundifolia*	Vitaceae	ABNC observation
	Grape, Mustang	*Vitis candicans*	Vitaceae	ABNC observation
	Grass Love/Lace	*Eragrostis capillaris*	Poaceae	ABNC observation
	Grass, Annual Blue-	*Poa annua*	Poaceae	Brown (2001); Non-native
	Grass, Bahia-	*Paspalum notatum*	Poaceae	ABNC observation
	Grass, Barnyard	*Echinochloa crus-pavonis var. macer*	Poaceae	Brown (2001)
	Grass, Barnyard / Marsh Millet	*Echinochloa walteri*	Poaceae	Brown (2001)
	Grass, Bermuda	*Cynodon dactylon*	Poaceae	ABNC observation
	Grass, Blue-Eyed-	*Sisyrinchium langloisii*	Iridaceae	Brown (2001)
	Grass, Blue-Eyed-	*Sisyrinchium sagittiferum*	Iridaceae	Brown (2001)
	Grass, Carolina Jointtail-	*Coelorachis cylindrica*	Poaceae	Brown (2001)
	Grass, Carpet	*Axonopus affinis*	Poaceae	ABNC observation
	Grass, Dallis-	*Paspalum dilatatum*	Poaceae	Non-native
	Grass, Eastern Gama	*Tripsacum dactyloides*	Poaceae	ABNC observation
	Grass, Goose-	*Eleusine indica*	Poaceae	Brown (2001); Non-native
	Grass, Indian	*Sorghastrum nutans*	Poaceae	ABNC observation
	Grass, Johnson	*Sorghum halepense*	Sorghastrum	Non-native; invasive
	Grass, Jungle Rice-	*Echinochloa colona*	Poaceae	Brown (2001)
	Grass, Knotroot Bristle	*Seteria parviflora*	Poaceae	ABNC observation
	Grass, Little Blue-Eyed-	*Sisyrinchium minus*	Iridaceae	Brown (2001)
	Grass, Monkey	*Ophiopogon japonicus*	Liliaceae	Non-native
	Grass, Narrowleaf Silk-	*Pityopsis graminifolia*	Asteraceae	Brown (2001)
	Grass, Narrow-Leafed Blue-Eyed	*Sisyrinchium angustifolium*	Iridaceae	ABNC observation
	Grass, Needle Leaf Rosette	*Dichanthelium aciculare*	Poaceae	ABNC observation

Plants	Common Name	Genus Species	Family	Notes
	Grass, Rescue-	*Bromus catharticus*	Poaceae	Brown (2001); Non-native
	Grass, Rye-	*Loluym perenne*	Poaceae	Brown (2001); Non-native
	Grass, Silk	*Heterotheca graminifolia*	Asteraceae	ABNC observation
	Grass, Smut-	*Sporobulus indicus*	Poaceae	Brown (2001); Non-native
	Grass, Southern Crab-	*Digitaria ciliaris*	Poaceae	Brown (2001); Non-native
	Grass, Southern Cut-	*Leersia hexandra*	Poaceae	Brown (2001)
	Grass, St. Augustine	*Stenotaphrum secundatum*	Poaceae	Brown (2001); Non-native
	Grass, Sugarcane Plume	*Saccharum giganteum*	Poaceae	ABNC observation
	Grass, Switch-	*Panicum virgatum*	Poaceae	
	Grass, Texas Windmill	*Chloris texensis*	Poaceae	Listed in federal register as Category 2
	Grass, Variable Witch-	*Panicum divergens*	Poaceae	Brown (2001)
	Grass, Vasey	*Paspalum urvillei*	Poaceae	Non-native; invasive
	Grass, White-Eyed-	*Sisyrinchium rosulatum*	Iridaceae	Brown (2001); Non-native
	Grass, Whorled Panic	*Panicum pilocomayense*	Poaceae	Brown (2001)
	Grass, Widgeon	*Ruppia maritima*	Ruppiaceae	ABNC observation
	Grass, Windmill	*Chloris canterai*	Poaceae	Brown (2001)
	Greenbriar, Saw	*Smilax bona-nox*	Liliaceae	ABNC observation
	Hackberry, Sugar	*Celtis levigata*	Ulmaceae	ABNC observation
	Hawthorn, Parsley	*Crataegus marshallii*	Rosaceae	ABNC observation
	Heartseed	*Cardiospermum halicacabum*	Sapindaceae	Brown (2001); Non-native
	Hedeoma, Rough	*Hedeoma hispida*	Lamiacieae	Brown (2001)
	Hempvine / Climbing Hempweed	*Mikania scandens*	Asteraceae	ABNC observation
	Herbertia	*Herbertia lahue caerulea*	Iridaceae	ABNC observation
	Hercules Club / Tickle Tongue	*Zanthoxylum clava-herculis*	Rutaceae	ABNC observation
	Hickory, Bitternut	*Carya cordiformis*	Juglandaceae	Brown (2001)
	Hickory, Black	*Carya texana*	Juglandaceae	ABNC observation
	High Tide Bush / Iva	*Iva frutescens*	Asteraceae	ABNC observation
	Hogwort / Wooly Croton	*Croton capitatus*	Euphorbiaceae	ABNC observation
	Holly, Deciduous / Possum-Haw	*Ilex decidua*	Aquifoliaceae	ABNC observation
	Honeysuckle, Japanese	*Lonicera japonica*	Caprifoliaceae	Non-native; invasive
	Huisache	*Acacia farnesiana*	Fabaceae	
	Hyacinth, Water	*Eichornia crassipes*	Pontederiaceae	Non-native; invasive
	Hydrilla	*Hydrilla verticillata*	Hydrocharitaceae	Non-native; invasive
	Hyssop, Water	*Bacopa monnieri*	Scrophulariaceae	Brown (2001)
	Indian Paintbrush	*Castilleja indivisa*	Scrophulariaceae	Brown (2001)
	Indigo, Nodding Wild	*Baptisia bracteata*	Fabaceae	Brown (2001)
	Indigo, Yellow Wild/Erect Wild	*Baptisia sphaerocarpa*	Fabaceae	ABNC observation
	Ivy, Poison	*Toxicodendron radicans*	Anacardiaceae	ABNC observation; Syn. Rhus toxicodendron; Irritant
	Jessamine, Carolina	*Gelsemium sempervirens*	Loganiaceae	ABNC observation
	Larkspur	*Delphinium carolinianum*	Ranunculaceae	Brown (2001)
	Laurel, Carolina Cherry	*Prunus caroliniana*	Rosaceae	ABNC observation
	Lead Plant	*Amorph fruticosa*	Fabaceae	ABNC observation
	Leather-Flower	*Clematis crispa*	Ranunculaceae	Brown (2001)

Plants	Common Name	Genus Species	Family	Notes
	Lettuce, Water	*Pistia stratiotes*	Araceae	Non-native; invasive
	Ligustrum, Wax-Leaf	*Ligustrum licidum*	Oleaceae	Brown (2001); Non-native, invasive
	Lily, Canna	*Canna x generalis Bailey (pro sp.)*	Cannaceae	Non-native
	Lily, Rain	*Cooperia drummondii*	Amaryllidaceae	Brown (2001)
	Lily, Southern Swamp-	*Crinum americanum*	Amaryllidaceae	ABNC observation
	Lily, Spider	*Hymenocallis liriosme*	Amaryllidaceae	ABNC observation
	Lizard-Tail	*Saururus cernuus*	Saururaceae	ABNC observation
	Lobelia, Downy	*Lobelia puberula*	Campanulaceae	ABNC observation
	Lobelia, Flower	*Lobeia appendiculata*	Campanulaceae	Brown (2001)
	Locust, Honey	*Gleditsia triacanthos*	Fabaceae	
	Longtom	*Paspalum lividum*	Poaceae	Brown (2001)
	Loosestrife, Purple	*Lythrum lancelolatum*	Lythraceae	ABNC observation; Syn. Lythrum alatum; Non-native, invasive
	Lovegrass, Bigtop	*Eragrostis hirsuta*	Poaceae	ABNC observation
	Lovegrass, Elliott	*Eragrostis elliottii*	Poaceae	ABNC observation
	Lovegrass, Plains	*Eragrostis intermedia*	Poaceae	ABNC observation
	Lovegrass, Purple	*Eragrostis spectabilis*	Poaceae	ABNC observation
	Madder, Field	*Sherardia arvensis*	Roseaceae	Brown (2001); Non-native
	Marsh Elder / Seacoast Sumpweed	*Iva annua*	Asteraceae	ABNC observation
	Meadow Beauty	*Rhexia mariana*	Melastomataceae	ABNC observation
	Meadow Pink	*Sabatia campestris*	Gentianaceae	ABNC observation
	Melochia, Anglepod	*Melochia pyramidata*	Sterculaceae	Brown (2001)
	Melon, Musk-	*Cucumis melo*	Cucurbitaceae	Brown (2001); Non-native, invasive
	Mercardonia, Whiteflower	*Mecardonia acuminata*	Scrophulariaceae	ABNC observation
	Mexican Hat	*Ratibida columnifera*	Asteraceae	Brown (2001)
	Micromeria, Texas	*Micromeria brownei*	Lamiacieae	Brown (2001)
	Milfoil, Water-	*Myriophyllum spicatum*	Haloragaceae	ABNC observation
	Milk-Pea, Downy	*Galactia volubilis*	Fabaceae	ABNC observation
	Milkweed, Butterfly	*Asclepias tuberosa*	Asclepiadaceae	ABNC observation
	Milkweed, Whorled	*Asclepias verticillata*	Acelepiadaceae	Brown (2001)
	Milkwort, Whorled	*Polygala verticilata*	Polygalaceae	ABNC observation
	Mint, Mountain	*Pycnanthemum tenuifolium*	Lamiacieae	Brown (2001)
	Mint, Pink	*Stachys drummondii*	Lamiacieae	ABNC observation
	Mist Flower	*Eupatorium coelestinum*	Asteraceae	ABNC observation
	Moonseed, Carolina	*Cocculus carolinus*	Menispemaceae	ABNC observation
	Morning Glory, Common	*Ipomoea cordatotriloba*	Convolvulaceae	Brown (2001)
	Morning Glory, Salt-Marsh	*Ipomoea sagittata*	Convolvulaceae	ABNC observation
	Muhly, Gulf	*Muhlenbergia capillaris*	Poaceae	ABNC observation
	Mulberry, Red	*Morus rubra*	Moraceae	ABNC observation
	Mulberry, White	*Morus alba*	Moraceae	Brown (2001); Non-native
	Naiad	*Najas guadalupensis*	Najadaceae	ABNC observation
	Needlerush, Black	*Juncus roemarianus*	Juncaceae	ABNC observation

Plants	Common Name	Genus Species	Family	Notes
	Neptunia, Common / Yellow Puff	*Neptunia pubescens*	Fabaceae	ABNC observation
	Nettle, Carolina Horse-	*Solanum carolinense*	Solanaceae	ABNC observation
	Nightshade, Black	*Solanum ptychanthum*	Solanaceae	Brown (2001)
	Nits-and-Lice	*Hypericum drummondii*	Hypericaceae	ABNC observation
	Noseburn	*Tragia bentonicifolia*	Euphorbiaceae	ABNC observation
	Nutrush	*Scleria oligantha*	Cyperaceae	Brown (2001)
	Nutrush, Fewflower	*Scleria pauciflora*	Cyperaceae	ABNC observation
	Nutrush, Fringed	*Scleria ciliata*	Cyperaceae	ABNC observation
	Oak, Cherrybark	*Quercus falcata*	Fagaceae	ABNC observation
	Oak, Live	*Quercus virginiana*	Fagaceae	ABNC observation
	Oak, Post	*Quercus stellata*	Fagaceae	ABNC observation
	Oak, Water	*Quercus nigra*	Fagaceae	ABNC observation
	Oak, Willow	*Quercus phellos*	Fagaceae	ABNC observation
	Onion, Wild	*Allium canadense*	Liliaceae	Brown (2001)
	Orange, Trifoliate	*Citrus trifoliata*	Rutaceae	ABNC observation
	Osage Orange	*Maclura pomifera*	Moraceae	ABNC observation
	Palmetto, Dwarf	*Sabal minor*	Palmae	ABNC observation
	Panicgrass, Berg's	*Panicum pilcomayense*	Poaceae	ABNC observation
	Panicum, Beaked	*Panicum anceps*	Poaceae	ABNC observation
	Panicum, Fall	*Panicum dichotomiflorum*	Poaceae	Brown (2001)
	Panicum, Gaping	*Panicum hians*	Poaceae	ABNC observation
	Panicum, Texas	*Panicum texanum*	Poaceae	ABNC observation
	Parkinsonia / Retama	*Parkinsonia aculeata*	Fabaceae	ABNC observation
	Parsley, Hedge-	*Torilis arvensis*	Apiaceae	Brown (2001); Non-native
	Parsley, Knotted Hedge-	*Torilis nodosa*	Apiaceae	Brown (2001); Non-native
	Parsley, Prairie	*Polytaenia nuttalli*	Apiaceae	ABNC observation
	Parsley, Sand-	*Amnoselinum butleri*	Apiaceae	Brown (2001)
	Parsley, Swamp	*Trepocarpus aethusae*	Apiaceae	ABNC observation
	Paspalum, Brownseed	*Paspalum plicatulum*	Poaceae	ABNC observation
	Paspalum, Florida	*Paspalum floridanum*	Poaceae	ABNC observation
	Passionflower / (White) Maypop	*Plassiflora incarnata*	Passifloraceae	ABNC observation
	Pea, Butterfly	*Centrosema virginianum*	Fabaceae	ABNC observation
	Pea, Deer	*Vigna luteola*	Fabaceae	ABNC observation
	Pea, Hoary	*Tephrosia onobrychoides*	Fabaceae	Brown (2001)
	Pea, Partridge	*Cassia fasciculata*	Fabaceae	ABNC observation
	Pear, Callery	*Pyrus calleryana*	Roseaceae	Brown (2001)
	Pecan	*Carya illinoensis*	Juglandaceae	ABNC observation
	Pellitory	*Parietaria pensylvanica*	Urticaceae	Brown (2001)
	Pennywort, Round/Water	*Hydrocotyle umbellata*	Apiaceae	ABNC observation
	Peppergrass	*Lepidium virginicum*	Brassicaceae	Brown (2001)
	Pepper-Vine	*Ampelopsis arborea*	Vitaceae	ABNC observation
	Persimmon, Common	*Diospyros virginiana*	Ebenaceae	ABNC observation
	Petunia, Wild	*Ruellia nudiflora*	Acanthaceae	Brown (2001)
	Phragmites / Sea Cane	*Phragmites australis*	Poaceae	ABNC observation
	Pickerelweed	*Ponterderia cordata*	Pontederiaceae	ABNC observation

Plants	Common Name	Genus Species	Family	Notes
	Pimpernel, Scarlet	*Anagallis arvensis*	Primulaceae	Non-native
	Pine, Loblolly	*Pinus taeda*	Pinaceae	ABNC observation
	Pine, Slash	*Pinus elliottii*	Pinaceae	ABNC observation
	Plantain, Indian	*Plantago lanceolata*	Asteraceae	ABNC observation; Syn. *Cacalia lancelolata;* Brown (2001), non-native
	Plantain, Lanceleaf Indian	*Arnoglossum ovatum*	Asteraceae	Brown (2001)
	Plantain, Redseed	*Plantago rhodosperma*	Plantaginaceae	Brown (2001)
	Plantain, Southern	*Plantago virginica*	Plantaginaceae	Brown (2001)
	Pokeberry	*Phytolacca americana*	Phytolaccaceae	ABNC observation
	Pony Foot	*Dichondra carolinensis*	Convolvulaceae	ABNC observation
	Primrose, Showy Evening/Mexican	*Oenothera speciosa*	Onagraceae	ABNC observation
	Primrose, Smooth Water	*Ludwigia peploides*	Onagraceae	Brown (2001)
	Privet, Chinese	*Ligustrum sinense*	Oleaceae	Non-native; invasive
	Privet, Japanese	*Ligustrum japonica*	Oleaceae	Non-native; invasive
	Privet, Upland	*Forestiera ligustrina*	Oleaceae	ABNC observation
	Privet, Upland	*Mimosa strigillosa*	Fabaceae	Brown (2001)
	Puff, Yellow Powder-	*Neptunia lutea*	Fabaceae	Brown (2001)
	Ragweed	*Ambrosia artemisiifolia*	Asteraceae	Brown (2001)
	Ragweed, Giant	*Ambrosia trifida*	Asteraceae	ABNC observation
	Ragweed, Western	*Ambrosia psilostachya*	Asteraceae	ABNC observation; Syn. *Ambrosia cumanensis*
	Ratany, Trailing	*Krameria lanceolata*	Krameriaceae	Brown (2001)
	Rattlebox, Drummond	*Sesbania drummondii*	Fabaceae	ABNC observation
	Rattlesnake Master	*Eryngium yuccifolium*	Apiaceae	Brown (2001)
	Rose-Mallow, Halberd-Leaved	*Hibiscus militaris*	Malvaceae	ABNC observation
	Rosinweed, Simpson	*Silphium gracile*	Asteraceae	Brown (2001)
	Ruellia, Hairy	*Ruellia humilis*	Acanthaceae	ABNC observation
	Rush, Forked	*Juncus dichotomus*	Juncaceae	Brown (2001)
	Rush, Inland	*Juncus interior*	Juncaceae	Brown (2001)
	Rush, Knotleaf	*Juncus acuminatus*	Juncaceae	Brown (2001)
	Rush, Needle-	*Juncus effusus*	Juncaceae	ABNC observation
	Rush, Round-Head	*Juncus validus*	Juncaceae	ABNC observation
	Rush, Slimpod	*Juncus diffusissimus*	Juncaceae	Brown (2001)
	Rush, Stout	*Juncus nodatus*	Juncaceae	Brown (2001)
	Rush, Twoflower / Grassleaf	*Juncus marginatus*	Juncaceae	ABNC observation
	Rush, Whiteroot	*Juncus brachycarpus*	Juncaceae	ABNC observation
	Rye, Wild-	*Elymus virginicus*	Poaceae	Brown (2001)
	Sage, Blue	*Salvia azurea*	Lamiacieae	ABNC observation
	Sage, Lyre-Leaf	*Salvia lyrata*	Lamiacieae	ABNC observation
	Sage, Tropical	*Salvia coccinea*	Lamiacieae	ABNC observation
	Sage, Wood	*Teucrium canadense*	Lamiacieae	Brown (2001)
	Sandwort	*Arenaria serpyllifolia*	Caryophyllaceae	Brown (2001); Non-native
	Sea Myrtle / Baccharis	*Baccharis halimifolia*	Asteraceae	ABNC observation
	Sedge, Bladder	*Carex intumescens*	Cyperaceae	ABNC observation

Plants	Common Name	Genus Species	Family	Notes
	Sedge, Britton's	*Carex tetrastachya*	Cyperaceae	Brown (2001)
	Sedge, Bush's	*Carex bushii*	Cyperaceae	Brown (2001)
	Sedge, Carolina	*Carex caroliniana*	Cyperaceae	ABNC observation
	Sedge, Cherokee	*Carex cherokeensis*	Cyperaceae	ABNC observation
	Sedge, Crowfoot	*Carex crus-corvii*	Cyperaceae	Brown (2001)
	Sedge, Deeprooted	*Cyperus entrerianus*	Cyperaceae	ABNC observation; non-native; invasive
	Sedge, Flattened	*Carex complanata*	Cyperaceae	ABNC observation
	Sedge, Frank's	*Carex frankii*	Cyperaceae	ABNC observation
	Sedge, Hop-	*Carex lupulina*	Cyperaceae	Brown (2001)
	Sedge, Kidney-Shaped	*Carex reniformis*	Cyperaceae	Brown (2001)
	Sedge, Long's	*Carex longii*	Cyperaceae	Brown (2001)
	Sedge, Narrowleaf	*Carex leavenworthii*	Cyperaceae	Brown (2001)
	Sedge, Short Beak	*Carex brevior*	Cyperaceae	Brown (2001)
	Sedge, Sweet	*Cyperus pseudovegetus*	Cyperaceae	ABNC observation
	Sedge, Thinfruit	*Carex flaccosperma*	Cyperaceae	ABNC observation
	Sedge, White-Topped	*Rhynchospora colorata*	Cyperaceae	ABNC observation
	Sedge, Yellow Fruit	*Carex annectens*	Cyperaceae	Brown (2001)
	Seedbox, Creeping	*Ludwigia glandulosa*	Onagraceae	ABNC observation
	Seedbox, Marsh	*Ludwigia palustris*	Onagraceae	ABNC observation
	Seedbox, Narrowleaf	*Ludwigia lineraris*	Onagraceae	ABNC observation
	Seedbox, Shrubby	*Ludwigia octovalvis*	Onagraceae	Brown (2001)
	Selfheal	*Purnella vulgaris*	Lamiacieae	Brown (2001)
	Shepherds-Needle	*Scandix pecten-vernis*	Apiaceae	Brown (2001); Non-native
	Skullcap	*Scutellaria racemosa*	Lamiacieae	Brown (2001); Non-native
	Skullcap, Drummond	*Scutellaria drummondii*	Lamiacieae	Brown (2001)
	Smartweed, Water / Water Pepper	*Polygonum hydopiperoids*	Polygonaceae	ABNC observation
	Snakeroot, White	*Eupatorium rugosum*	Asteraceae	ABNC observation
	Sneezeweed, Purplehead	*Helenium flexuosum*	Asteraceae	Brown (2001)
	Snow-on-the-Prairie	*Euphorbia bicolor*	Euphorbiaceae	ABNC observation
	Soapberry, Western	*Sapindus saponaria*	Sapondaceae	ABNC observation
	Sorrel, Rose Wood	*Oxalis debilis*	Oxalidaceae	Brown (2001); Non-native
	Sorrel, Wood / Sour Grass	*Oxalis dillenii*	Oxalidaceae	ABNC observation
	Spadeleaf	*Centella erecta*	Apiaceae	Brown (2001)
	Spanish Moss	*Tillandsia useneoides*	Bromeliaceae	ABNC observation
	Speenwort, Ebony	*Asplenium platyneuron*	Aspleniaceae	ABNC observation
	Spiderwort, Hairy Flowered	*Tradescantia hirsutiflora*	Commelinaceae	ABNC observation
	Spiderwort, Ohio	*Tradescantia ohiensis*	Commelinaceae	Brown (2001)
	Spikerush	*Eleocharis montevidensis*	Cyperaceae	Brown (2001)
	Spikerush, Squarestem	*Eleocharis quadrangulata*	Cyperaceae	ABNC observation
	Spikesedge, Smallseed	*Eleocharis microcarpa*	Cyperaceae	ABNC observation
	Spotflower, Creeping	*Acmella oppositifolia*	Asteraceae	ABNC observation
	Spot-Flower, Creeping	*Spilanthes americana*	Asteraceae	ABNC observation
	Spring Ladies-Tresses	*Spiranthes vernalis*	Orchidaceae	ABNC observation

Plants	Common Name	Genus Species	Family	Notes
	Spurge, Mat	*Euphorbia serpens*	Euphorbiaceae	Brown (2001)
	Spurge, Warty	*Euphorbia spathulata*	Euphorbiaceae	Brown (2001)
	St. Andrew's Cross	*Ascyrum hypericoides*	Hypericaceae	ABNC observation
	St. Peter's Wort	*Hypericum crux-andreae*	Hypericaceae	Brown (2001)
	Starwort, Chickweed	*Stellaria media*	Caryophyllaceae	Brown (2001); Non-native
	Sumpweed, Narrow-leaf	*Iva angustifolia*	Asteraceae	ABNC observation
	Sunflower, Annual	*Helianthus annuus*	Asteraceae	Brown (2001)
	Sunflower, Maximilian	*Helianthus maximiliani*	Asteraceae	ABNC observation
	Sunflower, Swamp/Narrowleaf	*Helianthus angustifolia*	Asteraceae	Brown (2001)
	Sunshade, Dog	*Linmosciadium pumilum*	Apiaceae	Brown (2001)
	Supple-Jack / Rattan Vine	*Berchemia scandens*	Rhamnaceae	ABNC observation
	Sweetgum	*Liquidambar styraciflua*	Hamamelidaceae	ABNC observation
	Sycamore, American	*Platanus occidentalis*	Platanaceae	ABNC observation
	Tallow, Chinese	*Triadica sebifera*	Euphorbiaceae	ABNC observation; non-native; invasive
	Texas Prairie Dawn	*Hymenoxys texana*	Asteraceae	ABNC observation; Endangered
	Thalia, Powdery	*Thlia dealbata*	Marantaceae	
	Thistle, Bull	*Cirsium horridulum*	Asteraceae	Brown (2001)
	Thistle, Sow	*Sonchus asper*	Asteraceae	Non-native
	Thoroughwort, Hyssopleaf	*Eupatorium hyssopifolium*	Asteraceae	Brown (2001)
	Thoroughwort, Late / Lateflowering	*Eupatorium serotinum*	Asteraceae	ABNC observation
	Three Awn, Old Field	*Aristida oligantha*	Poaceae	Brown (2001)
	Three Awn, Purple	*Aristida purpurascens*	Poaceae	ABNC observation
	Three Awn, Slimspike	*Aristida longespica*	Poaceae	Brown (2001)
	Three-Square, Leafy	*Scirpus robustus*	Cyperaceae	ABNC observation
	Tickseed, Lanceleaf	*Coreopsis lanceolata*	Asteraceae	Brown (2001)
	Tick-Trefoil / Clover	*Desmonium* sp.	Fabaceae	ABNC observation
	Tooth Cup	*Ammannia coccinea*	Lythraceae	Brown (2001)
	Tridens, Longspike	*Tridens strictus*	Poaceae	ABNC observation
	Turk's Cap	*Malvaviscus arboreus drummondi*	Malvaceae	ABNC observation
	Venus-Looking-Glass	*Triodanis perfoliata var. perfoliata*	Campanulaceae	Brown (2001)
	Venus-Looking-Glass	*Triodanis perfoliata var. biflora*	Campanulaceae	Brown (2001)
	Vervain, Brazilian	*Verbena brasiliensis*	Verbenaceae	ABNC observation; non-native
	Vervain, Tuber	*Verbena rigida*	Verbenaceae	ABNC observation
	Vetch, Deer Pea	*Vicia ludoviciana*	Fabaceae	ABNC observation
	Vetch, Sessile Flowered	*Vicia sativa*	Fabaceae	Brown (2001); Non-native
	Vetch, Smallflowered	*Vicia minutiflora*	Fabaceae	Brown (2001)
	Wafer Ash / Hoptree	*Ptelea trifoliata*	Rutaceae	ABNC observation
	Waterhemp, Gulf Coast	*Amaranthus australis*	Amaranthaceae	ABNC observation
	Waterleaf, Blue	*Hydrolea ovata*	Hydrophyllaceae	ABNC observation
	Wax Myrtle	*Myrica cerifera*	Myricaceae	ABNC observation
	Weed, Alligator	*Alternanthera philoxeroides*	Amaranthaceae	ABNC observation; non-native, invasive

Plants	Common Name	Genus Species	Family	Notes
	Weed, Bitter-	*Helenium amarum*	Asteraceae	ABNC observation
	Weed, Blue-	*Aster subulatus*	Asteraceae	Brown (2001)
	Weed, Fringed Sneeze	*Helenium drummondii*	Asteraceae	ABNC observation
	Weed, Frost	*Verbesnia virginica*	Asteraceae	ABNC observation
	Weed, Horse-	*Conyza canadensis*	Asteraceae	Brown (2001)
	Weed, Long-leaf Pond-	*Potamogenton nodosus*	Potamogetonaceae	ABNC observation
	Weed, Missouri Iron	*Vernonia missurica*	Asteraceae	ABNC observation
	Weed, Mouse-Eared Chick-	*Cerastium glomeratum*	Caryophyllaceae	Brown (2001); Non-native
	Weed, Purple Cud-	*Gnaphalium purpureum*	Asteraceae	ABNC observation
	Weed, Rough Button-/Trailing Button-	*Diodia teres*	Rubiaceae	ABNC observation
	Weed, Spotted Smart-	*Polygonum punctatum*	Polygonaceae	Brown (2001)
	Weed, Virginia Button-	*Diodia virginiana*	Rubiaceae	ABNC observation
	Weed, Wax-	*Cuphea glutinosa*	Lythraceae	Brown (2001); Non-native
	Weed, Yankee	*Eupatorium compositifolium*	Asteraceae	ABNC observation
	Willow, Black	*Salix nigra*	Salicaceae	ABNC observation
	Willow, Lance-Leaved Water	*Justicia ovata*	Acanthaceae	Brown (2001)
	Wintergrass, Texas / Texas Speargrass	*Stipa leucotricha*	Poaceae	ABNC observation
	Wolfberry, Carolina	*Lycium carolinianum*	Solanaceae	ABNC observation
	Woodoats	*Chasmanthium laxum*	Poaceae	ABNC observation
	Woodoats, Narrowleaf	*Chasmanthium sessiliflorum*	Poaceae	ABNC observation
	Yaupon	*Ilex vomitoria*	Aquifoliaceae	ABNC observation

PHOTO BY STEPHAN MYERS

A Plant Checklist of a Harris County Flood Control Detention Basin, January 2001

Larry E. Brown, Houston Community College, 1300 Holman Avenue, Houston TX 77004

This checklist is dedicated to Ralph Taylor of the Harris County Flood Control District for his interest in the local flora, for encouraging the development of the checklist, and for his discovery of one of the rarest Texas plants (Cyperus cephalanthus) in this detention basin.

Introduction

The following is a checklist of all the vascular plants, native and introduced, that are present on the Harris Flood Control Basin located south of Spencer Highway in Pasadena. The checklist is based upon monthly trips beginning on March 21, 2000 and ending on September 23, 2000.

This site is a remnant native prairie positioned east of the Texas Chiropractic College and west of a trailer park housing site. It is north of Little Vince Bayou and southeast of the Beltway / Spencer Highway intersection. Prairie vegetation surrounds a detention basin that has been dug adjacent to the chiropractic college to alleviate downtown flooding along Little Vince Bayou, which flows southeast into Armand Bayou. The only other disturbance sites are a pipeline right of way across a section of the site and a deposit of dirt fill along a portion of the pipeline right of way.

Most of the plant species are typical of a prairie including species that are found in prairie pot hole wet habitats. Weedy species grow around and in the detention basin and on the deposit of dirt.

During the seven months of fieldwork, the following habitats were identified along with some species that are found only or mostly in these habitats.

Prairie: This is the largest plant community. The following are some of the plants of this habitat, *Manfreda virginica, Eryngium uccifolium, Ascepias verticillata, Ambrosia psilostachya, Atser ericoides, Helianthus maximillani, Liatris pycnostachya, Pityopsis graminifolia, Sceleria ciliata, Dalea candida var. candida, Krameria lanceolata, Bouteloua curtipendula, Coelorachis cylindrical, Muhlenbergia capillaries, Schizachyrium scoparium, Salvia azure, Tridens strictus, Tripsacum dactyloides*, and *Andropogon gerardii*.

Plants of disturbed areas: These plants are in the detention basin depression, on fill dirt and on the prairie margins. The typical plants are, *Cynodon dactylon, Chloris canteria, Bothriochloa ischaemem, Torilis arvensis, Torilis nodosa, Aster subulatus, Helianthis annuus, Hypichaeris microcephala, Pyrrhopappus pauciflorus, Senecio tampicanus, Solidago Canadensis, Sonchis asper, Medicago lupulina, M. polymorpha, Trifolium repens, Alllim canadense, Ambrosia trifida, Paspalum urvillei*, and *Nothoscordium*.

Plants of wet flood control ditches: Some plants here are, *Alternanthera philoxeroides, Ludwigia peploides* and *Amaranthus rudis*.

Plants of the prairie wetlands: Some of the plants here are, *Acmella oppositifolia, Panicum virgatum, Sagittaria* (two species), *Justicia ovata, Carex crus-ccorvii, Carew lupulina, Cyperis cephalanthus, Spartina pectinata, Cyperus haspan, Sesbania drummondii, Leersia hexandra*, and *Paspalum lividum*.

The following are significant plant finds and some comments about their significance:

- *Aster ericoides* L. This is a rare species in the Houston area. It is usually found only in pristine prairies.
- *Eupatoriom hyssopufolium* L. This is another rare species in the Houston area. It is found only in high quality prairies.
- *Cyperus cephalanthus* T. & H. This is one of the rarest plants in Texas, if not the rarest. It was first discovered in Texas in 1835 near Galveston Bay with the exact locality unknown. It has not been seen since in Texas until Ralph Taylor discovered a population at this site in 1999. In 1993, Carter and McInnis published a status report on this species and reported 18 sites in the Louisiana coastal prairies. In Texas, they searched for it in the coastal prairies of Chambers and Harris counties but without success. Because of the construction pending at the detention basin, Ralph Taylor has transferred most of the plants of this species to the nursery at the Greens Bayou Mitigation Bank, where they are now growing. After the proposed construction is completed here, it may be possible to transfer some plants back to the original site.
- *Trifolium pratense* L. This is my first Harris County collection of this agronomic clover. In the northern states it is planted for pasture improvement. A few plants were growing along the detention basin and arrived here probably in a ground cover seed mixture.
- *Krameria lanceolata* Torr. In the Houston area this prostrate herb with orchid-like flowers has been found in Harris and Waller counties. This is the second Harris County collection.
- *Cuphea glutinosa* Cham & Schlecht. This is the first Harris County record for this prostrate herb that is native to South America.
- *Bothriochloa Exaristata* (Nash) Henr. This grass, endemic to coastal prairies in southeast Texas and southwest Louisiana, is on the watch list of Texas most endangered species list. This is one of the few Harris county sites.
- *Coelorachis cylindrical* (Michx.) Nash This is another

Table 1 Taxanomic Analysis of the Flora

Family	Genera	Species
Acanthaceae	2	3
Alismataceae	1	2
Amaranthaceae	2	2
Amaryllidaceae	2	2
Anacardiaceae	1	1
Apocynaceae	2	2
Asclepiadaceae	1	2
Brassicaceae	1	1
Campanulaceae	2	2
Caprifoliaceae	2	2
Caryophyllaceae	3	3
Commrlinaceae	2	2
Convolvulaceae	3	4
Cornaceae	1	1
Cupressaceae	1	1
Cyperaceae	6	30
Ebenaceae	1	1
Euphorbiaceae	4	7
Fabaceae	14	27
Gentianaceae	2	2
Geraniaceae	1	1
Hypericaceae	1	2
Iidaceae	2	5
Juglandaceae	1	1
Juncaceae	1	6
Krameriaceae	1	1
Liliaceae	1	2
Lythraceae	3	3
Malvaceae	3	4
Moraceae	1	1
Myricaceae	1	1
Oleaceae	2	4
Onegraceae	3	5
Orchidaceae	1	1
Oxalidaceae	1	2
Passifloraceae	1	1
Plantaginaceae	1	3
Poaceae	33	54
Polygonaceae	2	5
Primulaceae	1	1
Ranunculaceae	3	3
Rhamnaceae	1	1
Rosaceae	2	3
Salicaceae	2	2
Sapindaceae	1	1
Scrophulariaceae	4	4
Solanaceae	2	2
Sterculiaceae	1	1
Typhaceae	1	2
Ulmaceae	2	2
Urticaceae	1	1
Valerianaceae	1	1
Verbenaceae	2	3
Vitaceae	1	1
FAMILIES	GENERA	SPECIES
Total 56	183	291

rare prairie grass species. This is the second Harris County record in the SBSC herbarium. The other collection is east of this site from a prairie along Spencer Highway near the intersection with Center Street.

- *Spartina pectinata*. This is an extremely rare prairie grass in Harris County and apparently in Texas. I surveyed the Tracy Herbarium at Texas A&M University and found only two 1930 collections from two counties in the Texas panhandle. In Harris County, this typical northern prairie pot hole species is found in the upper headwaters of the Armand Bayou drainage system. The other local records are to the southeast near the intersection of Beltway 8 and Fairmont Parkway. Here one plant shared a low moist area with Cyperus cephalanthus. The coordinates of the site are 29°39′39″N and 95°08′50″W.

The species list beginning on page six is arranged alphabetically by family, genus and species. The first two columns indicates the origin, i.e. **N** for those plants that are native to the United States, **I** for the non-native usually woody taxa. The second two columns indicates the form, i.e. woody or herbaceous. The third three columns indicates the principal flowering season, i.e. **V** for vernal (from late February to June), **S** for summer (from June through August), **F** for fall (from September through November and **W** for winter (December through early February). None of our species have their principal flowering period in winter.

Table 1 indicates that 56 families, 183 genera and 291 species were found during the study period from March 2000 through September 2000. The five largest families are the Poaceae with 33 genera and 63 species, the Asteracea with 32 genera and 47 species, the Cyperacae with 6 genera and 30 species, the Fabacea with 14 genera and 27 species and the Apiaceanae with 11 genera and 12 species.

The number of families (56) and species (291) on this small site in southern Harris County are comparable to the 108 families and 599 species on the larger 256 acres Mercer Arboretum along Cypress Creek in the northern portion of the county. The smaller detention basin species is due to the small size of the detention basin, the dominance of the prairie habitat and the absence of any significant habitats.

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Appendix F. Water Quality Data

Assessment Methodology

To assess the current state of the watershed, 1998-2003 water quality data were analyzed, primarily from the Texas Commission on Environmental Quality (TCEQ) database, which includes data collected by state agencies, river authorities, county and local governments and volunteer citizen monitors. From the data set, the following key parameters were chosen for this watershed analysis:

- Salinity
- Dissolved oxygen
- Chlorophyll-a
- Nutrients
- Fecal coliform bacteria
- Water clarity (turbidity)
- Sediment chemistry
- Fish kill data

The water quality data were partitioned into seven distinct reaches of Armand Bayou. Four are on the mainstem:

- Mud Lake (the lower tidal reach downstream of the confluence with Horsepen Bayou to the Nasa Parkway bridge)
- Middle Tidal (from the confluence with Horsepen Bayou to the confluence with Big Island Slough, including Bay Area Boulevard and Bay Area Park)
- Upper Tidal (near Oil Field Road)
- Above Tidal (near Genoa-Red Bluff Road)

The other three reaches represent major tributaries:

- Spring Gully
- Big Island Slough
- Horsepen Bayou

Because the data was not consistently collected in all reaches of the bayou or for all parameters of interest, the number of samples available for analysis is indicated for each parameter and reach. The only data available for Spring Gully since 1998 are a few samples from the special study in 1999, so it is not included in the discussions. In addition to this compilation of current data, the entire period of record was analyzed to see if any discernable trends could be identified in the individual reaches for the parameters considered.

Salinity

Salinity is the measure of the amount of dissolved salts in a solution. Salinity is usually determined indirectly by measuring a physical property such as electrical conductivity, which is the ability of a solution to carry an electrical current, and is measured in μmhos/cm. The salt content of freshwater is generally described in terms of its conductivity, which is usually less than 1000 μmhos/cm. Salt water is usually described in terms of its salinity. Salinity is less than 1 part per thousand (ppt) in fresh water and about 35 ppt in the Gulf of Mexico.

The average surface salinity for Mud Lake was 6.7 ppt and it was 2.0 ppt for the Middle Tidal reach. Maximum surface salinities for these two areas reached 20.6 ppt and 12.2 ppt for Mud Lake and Middle Tidal, respectively. Surface waters in the Upper Tidal and above tidal areas had variable conductivity values below 800 μmhos/cm, which is normal for freshwater streams. Big Island Slough and Horsepen Bayou had conductivity values indicating periods of freshwater up to one sample in Horsepen Bayou with a conductivity of 9600 μmhos/cm, which corresponds to a salinity of 5.5 ppt. (Table 1) Essentially, the data show that Armand Bayou is a freshwater to low salinity system.

Dissolved Oxygen

At normal saturation levels, the concentration of dissolved oxygen in Galveston Bay is between 7 and 9 mg/L, depending on water temperature and salinity. Several factors can change the dissolved oxygen levels, however. If excess algal growth occurs, very high dissolved oxygen concentrations (up to 15 or even 20 mg/L) may result. This happens when a great deal of photosynthesis takes place in the water, typically in sunny, warm conditions with high concentrations of nutrients that will allow excess algal growth.

Table 1. Surface (0.3 m depth) conductivity and salinity data from Armand Bayou from 1998 to 2003, where n is the number of measurements

		Specific Conductance (μmhos/cm)				Salinity (ppt)			
	Reach	Avg	n	min	max	Avg	n	min	max
1	Mud Lake	11030	35	372	32800	6.7	34	0.8	20.6
2	Middle Tidal	2669	63	154	20300	2.0	33	0.2	12.2
3	Upper Tidal	424	6	327	544	0.4	5	0.2	1.0
4	Above Tidal	506	27	100	800				
6	Big Island Slough	987	3	503	1940				
7	Horsepen Bayou	1777	79	158	9600				

Conversely, much lower dissolved oxygen levels can occur if there is high oxygen demand (e.g. unusually high numbers of organisms and algae) in the water. If the dissolved oxygen becomes very low (e.g. < 2 mg/L), then many aquatic organisms will not be able to survive. One instance where dissolved oxygen levels may become very low in a water body is at night if an algal bloom occurs, because the algae and the fish that feed on them are still using oxygen at night when no photosynthesis takes place. With their high daytime production and high nighttime oxygen demand, algal blooms cause a large diurnal swing in dissolved oxygen. In some cases these dissolved oxygen swings can be extreme enough to cause large fish kills.

In estuarine tributaries, the water is generally stratified, or layered, meaning that the deeper waters and the shallow waters are not well mixed. Much of this stratification is due to salinity, because high salinity water is heavier than lower salinity water. When possible, dissolved oxygen is measured at the surface (0.3 meters) and at various depths in the water column because significant differences in dissolved oxygen levels may occur at different depths if the layers are not well mixed. If the water is very shallow or if a dissolved oxygen meter with a cable is not available, the dissolved oxygen will just be measured at the 0.3-meter depth. To present this data on Armand Bayou, the surface (0.3 m) samples were compiled separately because they were available for each sampling event and they can be compared directly to one another. The limited data available on the deeper layers of the water column was compiled separately and is shown in the following table in the row below the surface data. The deeper parts of the water column generally had lower dissolved oxygen levels than the surface.

Overall, dissolved oxygen was lowest in the Upper Tidal reach, averaging 4.4 mg/L at the surface and 3.5 mg/L in the profile measurements (Table 2). Three of the six surface readings and nine of the 14 profile readings were below 4 mg/L, which is the TCEQ water quality standard for this segment. (Two of those nine profile readings would have been excluded from assessment based on temperature stratification.) The limited 24-hour monitoring (from continuously recording meters deployed overnight) also shows that this area has chronically low dissolved oxygen in the warmer months.

Oxygen levels in Mud Lake, Horsepen Bayou, and the Middle Tidal reaches were generally high, with only a few surface readings that fell below 4 mg/L (4% in Horsepen and Middle Tidal). The 24-hour monitoring also shows this pattern in the middle and lower tidal reaches.

Chlorophyll-a

Chlorophyll-a is typically used to measure the relative levels of phytoplankton in the water. Pheophytin-a is also sometimes measured, as it is "recently dead" chlorophyll. Sometimes the combination of these values is a better measure of the overall trophic condition (ability to support the food web) of a water body.

Average chlorophyll values were highest in Mud Lake, Middle Tidal, and Horsepen Bayou reaches, where the dissolved oxygen levels were also very high (Table 3). In the trend analysis, it appears that overall chlorophyll-a is decreasing, while pheophytin-a is increasing, however in the Mud Lake reach both chlorophyll and pheophytin may be increasing. Declines in chlorophyll-a are observed in many other areas of the Galveston Bay system as well. Effects of the declining chlorophyll-a concentrations on higher levels of the food chain are not yet known. Increases in chlorophyll-a appear to occur only in areas identified as eutrophic.

Table 2. Dissolved oxygen readings from Armand Bayou from 1998 – 2003, where n is the number of measurements

Reach		Dissolved Oxygen (mg/L)							
	(depth of samples)	Avg	n	min	max	Below 4 mg/L		Above 10 mg/L	
1	Mud Lake (0.3 m)	8.6	35	5.1	14.8	0	0%	7	20%
	Mud Lake (0.6 - 2.1 m)	7.2	16	4.9	10.0	0	0%		
2	Middle Tidal	8.8	82	3.0	21.6	3	4%	23	28%
	Bay Area Blvd (1.1 - 2.7 m)	6.1	33	0.2	13.1	7	21%	0	0%
3	Upper Tidal	4.4	6	2.5	7.9	3	50%	0	0%
	Upper Tidal (0.6 - 3.0 m)	3.5	14	0.9	7.6	9	64%		
4	Above Tidal	6.2	38	3.3	9.1	7	18%	0	0%
6	Big Island Slough	8.1	3	7.2	8.6	0	0%	0	0%
	Big Island Slough (0.6 - 1.5 m)	6.1	3	4.9	7.1	0	0%	0	0%
7	Horsepen Bayou	7.8	99	2.5	15.0	4	4%	20	20%
	Horsepen Bayou (0.9 - 2.7 m)	6.0	9	0.5	12.2	3	33%	0	0%

Nutrients

Total phosphorus and ammonia values tended to be highest in Horsepen Bayou, while Mud Lake and Middle Tidal had relatively high phosphorus concentrations (Table 4). Average ammonia was generally low in the other reaches.

Fecal Coliform Bacteria

Based upon the screening level, fecal coliform bacteria counts were high in about 20% of the samples considered here, with no obvious differences between the reaches (Table 5). Table 5 presents fecal coliform data from Armand Bayou (1998 - 2003) compared to the TCEQ water quality screening level. The current assessment guidance lists a waterbody as impaired for bacteria if >25% of the samples exceed the screening level.

Water Clarity (Turbidity)

Water clarity averaged a little lower in the Mud Lake and Middle Tidal reaches than the other reaches (Table 6). Total suspended solids were also highest in Mud Lake and Middle Tidal. The trend analysis indicated that water clarity (secchi depth) in Horsepen Bayou appears to have shown some improvement from 1990 to the present.

Sediment Contaminants

Sediment was sampled for metals only twice in 2002 by the TCEQ. Copper, cadmium, mercury, zinc, lead and arsenic did not exceed any state screening levels. However, chromium and nickel slightly exceeded the state 85th percentile at the Middle Tidal station in one of the two samples. Barium exceeded the state 85th percentile at the Upper Tidal station in both of the samples. The 85th percentile is a value computed from the TCEQ database that is higher than 85% of the samples collected from tidal streams. A sample that exceeds the this number is relatively high but will not necessarily cause adverse effects. While nickel, chromium and barium exceeded the 85th percentile, they did not exceed any effects-based screening levels.

Fish Kill Data

TPWD maintains an inventory of fish kills and pollution complaints in its Pollution Response Inventory and Species Mortality (PRISM), with records existing as early as the 1970's. (Records from the 1970's and early 1980's may be incomplete.) Fish Kill and pollution events in the Armand Bayou watershed are investigated by staff from TPWD's Dickinson office, often in collaboration with TCEQ staff.

TPWD records indicated that seven fish kills have been recorded in the Armand Bayou watershed since 1971.

Table 3. Chlorophyll-a and pheophytin a values from Armand Bayou (1998-2003), where n is the number of measurements.

	Chlorophyll-a (µg/L)				Chlorophyll-a + Pheophytin a			
Reach	Avg	n	min	max	Avg	n	min	max
1 Mud Lake	38.3	24	1	135	77.7	24	8.4	344.0
2 Middle Tidal	27.3	28	1	69.4	58.0	28	6.9	189.4
3 Upper Tidal	10.5	7	1	26	33.7	7	13.1	57.4
4 Above Tidal		0						
6 Big Island Slough	9.2	5	1	25.8	33.8	5	5.0	94.8
7 Horsepen Bayou	23.7	12	1	79.2	46.8	12	4.2	101.5

Table 4. Ammonia and phosphorus concentrations in Armand Bayou (1998 - 2003), where n is the number of measurements.

		Ammonia (mg/L)				Phosphorus (mg/L)			
	Reach	Avg	n	min	max	Avg	n	Min	max
1	Mud Lake	0.08	23	0.05	0.26	0.43	23	0.21	0.78
2	Middle Tidal	0.11	55	0.01	0.64	0.42	33	0.15	0.90
3	Upper Tidal	0.09	11	0.01	0.17	0.18	11	0.07	0.35
4	Above Tidal	0.12	11	0.01	0.35	0.19	5	0.10	0.40
5	Spring Gully	0.11	5	0.01	0.19	0.05	5	0.01	0.11
6	Big Island Slough	0.07	5	0.05	0.15	0.24	5	0.21	0.30
7	Horsepen Bayou	0.26	74	0.01	2.28	1.37	19	0.24	4.20

Table 5. Fecal Coliform values in Armand Bayou (1998 - 2003)

	Fecal Coliform, cfu/100ml					(Screening Level 400 cfu/100mL)	
	Reach	Average	N	Minimum	Maximum	# Exceeds	% Exceeds
1	Mud Lake	1167	32	10	30500	5	16%
2	Middle Tidal	1162	42	9	34000	9	21%
3	Upper Tidal	226	4	18	490	1	25%
4	Above Tidal	4023	2	45	8000	1	50%
6	Big Island Slough	50	2	27	72	0	0%
7	Horsepen Bayou	995	40	10	12000	10	25%

Table 6. Secchi and total suspended solids (TSS) data for Armand Bayou (1998 - 2003)

		Secchi (meters)				TSS (mg/L)			
	Reach	Avg	n	min	max	Avg	n	min	max
1	Mud Lake	0.34	31	0.15	0.7	45	24	19	99
2	Middle Tidal	0.32	50	0.15	3.5	36	42	4	90
3	Upper Tidal	0.55	4	0.2	1.02	21	6	12	35
4	Above Tidal	0.52	32	0.2	0.8	11	7	4	22
6	Big Island Slough	0.48	3	0.4	0.52				
7	Horsepen Bayou	0.54	29	0.2	1.15	16	81	1	62

Table 7. Historical fish kills in the Armand Bayou watershed

Start Date	Exact Location Name	Est. Total Killed	Cause	Event Description
4-20-71	Middle Bayou (Armand Bayou) from Bay Area Blvd. to Spring Gully.	500	Low Dissolved Oxygen	Approximately 500 fish were found dead in Middle Bayou (Armand Bayou).
7-30-79	Big Island Slough - One half mile East and one-half mile West of Red Bluff	352	Low Dissolved Oxygen	Fish kill in Big Island Slough, Harris County.
10-16-81	Drainage ditch in Brookforest subdivision — where ditch enters Horsepen Bayou	204	Low Dissolved Oxygen	Two hundred and four fish were killed in a drainage ditch in Brookforest subdivision.
01-25-97	Armand Bayou between Bay Area (above) and the golf course (below).	210	Cold front / freeze	An estimated 200 gar, less than 10 catfish, and some sunfish were observed dead in Armand Bayou, Harris County, Texas.
02-06-97	Drainage ditch that goes into Horsepen Bayou at Brook Forest Subdivision.	157	Unknown	
12-12-97	Spencer Highway and Big Island Slough	19,568	Gasoline	A spill of unleaded gasoline into Big Island Slough caused a fish kill of sunfish, largemouth bass, bullhead catfish, striped mullet, blue crab, crayfish, and minnows.
05-20-99	Willow Spring Creek downstream of Pasadena Blvd. to Canada Street.	182	Low Dissolved Oxygen	A fish kill occurred in Willow Spring creek due to low dissolved oxygen.

Appendix G. HCFCD Stream Designations

The Harris County Flood Control District uses a channel numbering system developed in 1945 to identify and catalog channels. The system utilizes a combination of letters and numbers, and does not reflect ownership by any public entity or identify property rights or maintenance responsibility.

Several channels and detention basins in the Armand Bayou watershed are known by local names. Some of these include:

Stream / Basin Name	HCFCD Number
Armand Bayou	B100-00-00
Horsepen Bayou	B104-00-00
Big Island Slough	B106-00-00
Spring Gully	B109-00-00
Willow Springs Bayou	B112-00-00
Spencer Highway Basin	B500-01-00
Fairmont Parkway Basin	B500-02-00
Red Bluff Road Basin	B500-04-00
Underwood Road Basin	B512-01-00
Baywood Basin	B513-02-00
Anthony Road Basin	B513-03-00

PHOTO BY STEPHAN MYERS

Appendix H. Basic Stream Facts

Reach/Location	Key Map	Description of Channel	Length (Ft.)	Detention Acreage
B100-00-00 (Armand Bayou)				
Clear Creek to NASA Partkway	619 QP	Natural Earthen Channel Section	2,521	
NASA Parkway to B101-00	619 PK	Natural Earthen Channel Section	2,950	
B101-00 to B104-00	619 KFB	Natural Earthen Channel Section	9,001	
B104-00 to Bay Area Blvd.	619 BA	Natural Earthen Channel Section	5,597	
Bay Area Blvd. to B106-00	619 A, 579 W	Natural Earthen Channel Section	1,172	
B106-00 to B105-00	579 W	Natural Earthen Channel Section	2,916	
B105-00 to B107-00	579 W	Natural Earthen Channel Section	3,147	
B107-00 to B108-00	579 WS, 578 V	Natural Earthen Channel Section	5,118	
B108-00 to B109-00	578 V	Natural Earthen Channel Section	2,859	
B109-00 to B110-00	578 R	Natural Earthen Channel Section	5,669	
B110-00 to B111-00	578 RQ	Natural Earthen Channel Section	6,199	
B111-00 to Genoa-Red Bluff Rd.	578 QL	Natural Earthen Channel Section	2,177	
Genoa-Red Bluff Rd. to B112-00	578 L	Natural Earthen Channel Section	2,098	
B112-00 to B113-00	578 L	Natural Earthen Channel Section	1,114	
B113-00 to B116-00	578 LGF	Natural Earthen Channel Section	3,763	
B116-00 to Fairmont Pkwy	578 F	Natural Earthen Channel Section	2,185	
Fairmont Pkwy to B115-00	578 FB	Natural Earthen Channel Section, Includes B500-02	3,684	
B115-00 to B114-00	578 FBA	Natural Earthen Channel Section, Includes B500-04	1,650	
B114-00 to Trebor Street	538 W, 578A	Natural Earthen Channel Section	1,281	
Trebor Street to B117-00	538 W	Natural Earthen Channel Section	1,641	
B117-00 to Spencer Highway	537 Z	Natural Earthen Channel Section, Includes B500-01	1,760	
Spencer Highway to Beltway 8	537 Z	Manmade Earthen Channel Section	2,092	
Beltway 8 to Pansy Street	537 ZY	Manmade Earthen Channel Section	2,566	
B101-00-00 (Cow Bayou)				
B100-00 to Space Center Blvd.	619 K	Manmade Earthen Channel Section	3,662	
B104-00-00 (Horsepen Bayou)				
B100-00 to B104-11	619 BAE	Natural Earthen Channel Section	2,989	
B104-11 to B104-01	619 E, 618 H	Natural Earthen Channel Section	4,811	
B104-01 to Bay Area Blvd	618 H	Natural Earthen Channel Section	3,076	
Bay Area Blvd. to B104-02	618 H	Natural Earthen Channel Section	1,062	
B104-02 to B104-08	618 HG	Natural Earthen Channel Section	1,376	
B104-08 to El Dorado Blvd.	618 G	Natural Earthen Channel Section	2,698	
El Dorado to B104-03	618 GF	Natural Earthen Channel Section	1,315	
B104-03 to B104-04	618 FB	Natural Earthen Channel Section	3,488	
B104-04 to B204-04	618 BA	Natural Earthen Channel Section	3,327	
B204-04 to B104-10	618 A	Natural Earthen Channel Section	1,541	
B104-10 to B104-05	618 A, 617 D	Natural Earthen Channel Section	1,457	
B104-05 to B104-06	617 D	Natural Earthen Channel Section, Adjacent to B504-04	2,412	

Reach/Location	Key Map	Description of Channel	Length (Ft.)	Detention Acreage
B104-06 to B104-09	617 DC	Natural Earthen Channel Section	4,599	
B104-09 to Upstream End	617 CB	Manmade Earthen Channel Section	4,208	
B104-01-00				
B104-00 to Space Center Blvd.	618 HM	Manmade Earthen Channel Section	2,186	
Space Center to Saturn Lane	618 MR	Manmade Earthen Channel Section	6,347	
B104-02-00				
B104-00 to Space Center Blvd.	618 HGL	Manmade Earthen Channel Section	4,909	
Space Center Blvd. to Neptune Lane	618 L	Manmade Earthen Channel Section	1,487	
Neptune Lane to Reseda Lane	618 L	Manmade Earthen Channel Section	2,242	
Reseda Lane to Upstream End	618 LQ	Manmade Earthen Channel Section	461	
B104-03-00				
B104-00 to B104-03-01	618 F	Natural Earthen Channel Section	1,279	
B104-03-01 to Space Center Blvd.	618 F	Manmade Earthen Channel Section	1,713	
Space Center Blvd. to Penn Hills Lane	618 F	Manmade Earthen Channel Section	1,138	
Penn Hills Lane to B104-03-02	618 FK	Manmade Earthen Channel Section	1,566	
B104-03-02 to El Dorado Blvd.	618 K	Manmade Earthen Channel Section	1,934	
El Dorado Blvd. to Reseda Drive	618 KP	No channel--Replaced by storm sewer	2,793	
B104-03-01				
B104-03 to Space Center Blvd.	618 F	Manmade Earthen Channel Section	1,657	
B104-03-02				
B104-03 to El Camino Real	618 KJ	Manmade Earthen Channel Section	1,945	
El Camino Real to Pebbleshire Drive	618 J	Manmade Earthen Channel Section	2,091	
Pebbleshire Drive to B104-03-02.1	618 JN	Manmade Earthen Channel Section	961	
B104-03-02.1				
B104-03-02 to B104-03-02.1A	618 N	Manmade Earthen Channel Section	2,066	
B104-03-02.1A to Buoy Road	618 N	Manmade Earthen Channel Section	2,098	
Buoy Rd. to El Toro Road	618 N	Manmade Earthen Channel Section	1,409	
El Toro to Elder Glen Dr.	618 NS	Manmade Earthen Channel Section	2,391	
B104-03-02.1A				
B104-03-02 to Barringer Lane	618 N, 617 RM	Manmade Concrete Lined Channel Section	1,769	
B104-04-00				
B104-00 to Clear Lake City Blvd.	618 B, 578 X	Manmade Earthen Channel Section	3,901	
Clear Lake City Blvd. to Private Road	578 XWS	Manmade Earthen Channel Section, Adjacent to B504-01 and B502-02	9,769	
Private Road to B104-04-02	578 SN	Manmade Earthen Channel Section	1,893	
B104-04-02 to B104-04-04	578 N, 577 R	Manmade Earthen Channel Section	4,527	
B104-04-04 to B111-05	577 RQ	Manmade Earthen Channel Section	1,777	
B111-05 to B111-04	577 Q	Manmade Earthen Channel Section	820	
B111-04 to B104-04-06	577 Q	Manmade Earthen Channel Section	1,987	
B104-04-02				
B104-04 to Genoa-Red Bluff	578 NJ	Manmade Earthen Channel Section	3,108	
B104-04-04				
B104-04 to Genoa-Red Bluff	577 RM	Manmade Earthen Channel Section	1,378	
B104-04-06				
B104-04 to Beltway 8	577 Q	Manmade Earthen Channel Section	1,311	

Reach/Location	Key Map	Description of Channel	Length (Ft.)	Detention Acreage
B104-05-00				
B104-00 to B104-05-01	617 DH	Natural Earthen Channel Section	3,386	
B104-05-01 to GH&H Railroad	617 HG	Natural Earthen Channel Section	2,649	
B104-05-01				
B104-05 to Clear Lake City Blvd.	617 H	Manmade Earthen Channel Section	1,206	
Clear Lake City Blvd. to Crescent Landing	617 H	Natural Earthen Channel Section	1,515	
Crescent Landing to Upstream End	617 H	Manmade Earthen Channel Section	1,024	
B104-06-00				
B104-00 to u/s end	617 D, 577 Z	Manmade Earthen Channel Section	5,298	
B104-08-00				
B104-00 to Hickory Knoll Drive	618 GC	Manmade Earthen Channel Section	3,804	
Hickory Knoll to Upstream End	618 C, 578 Y	Manmade Earthen Channel Section	2,082	
B104-09-00				
B104-00 to u/s end	617 C	Manmade Earthen Channel Section	1,643	
B104-10-00				
B104-00 to Clear Lake City Blvd.	618 A	Manmade Earthen Channel Section	1,123	
Clear Lake City Blvd. to Upstream End	618 AE	Manmade Earthen Channel Section	3,369	
B104-11-00				
B104-00 to Middlebrook Dr.	619 A	Natural Earthen Channel Section	2,629	
B105-00-00				
B100-00 to upstream end	579 W, 578 Z	Manmade Earthen Channel Section	2,711	
B106-00-00 (Big Island Slough)				
B100-00 to Red Bluff Road	579 WS	Natural Earthen Channel Section	6,166	
Red Bluff Road to Fairmont Parkway	579 TPKF	Natural Earthen Channel Section	15,873	
Fairmont Parkway to B106-02	579 FB	Natural Earthen Channel Section	2,000	
B106-02 to Spencer Highway	579 B, 539X	Natural Earthen Channel Section	2,831	
Spencer Highway to North H Street	539 XT	Natural Earthen Channel Section	3,754	
North H Street to B106-05	359 T	Natural Earthen Channel Section	1,710	
B106-05 to B106-06	539 T	Natural Earthen Channel Section	513	
B106-06 to North P Street	539 TP	Natural Earthen Channel Section	2,099	
North P Street to Railroad	539 PK	Natural Earthen Channel Section	4,809	
B106-02-00				
B106-00 to Old Hickory Drive	579 BC	Manmade Earthen Channel Section	2,234	
Old Hickory Dr. to Driftwood Drive	579 C	Manmade Earthen Channel Section	2,659	
B106-05-00				
B106-00 to North P Street	539 TP	Manmade Earthen Channel Section	2,573	
North P Street to Upstream End	539 P	Manmade Earthen Channel Section	1,872	
B106-06-00				
B106-00 to North P Street	539 TP	Natural Earthen Channel Section	1,673	
North P Street to Upstream End	539 P	Manmade Earthen Channel Section	1,422	
B107-00-00				
B100-00 to Clear Lake City Blvd.	579 W, 578 Z	Natural Earthen Channel Section	4,994	
Clear Lake City Blvd. to Upstream End	578 ZV	Manmade Earthen Channel Section	1,753	

Reach/Location	Key Map	Description of Channel	Length (Ft.)	Detention Acreage
B108-00-00				
B100-00 to upstream end	578 VUT	Manmade Earthen Channel Section	10,086	
B109-00-00 (Spring Gully)				
B100-00 to Red Bluff Road	579 SN	Natural Earthen Channel Section	1,191	
Red Bluff Road to Fairmont Parkway	579 NJE	Natural Earthen Channel Section	11,393	
Fairmont Parkway to B109-03	579 EA	Natural Earthen Channel Section	2,577	
B109-03 to Carlow Street	579 A	Manmade Earthen Channel Section	2,272	
Carlow Street to Andricks	579 A	Manmade Earthen Channel Section	1,354	
B109-03-00				
B109-00 to confluence w/ B112-02	579 A, 578 D	Manmade Earthen Channel Section	1,754	
B110-00-00				
B100-00 to upstream end	578 RQP	Manmade Earthen Channel Section	6,945	
B111-00-00				
B100-00 to Spurgem	578 Q	Natural Earthen Channel Section	1,995	
Spurgem to B111-02	578 QP	Natural Earthen Channel Section	2,155	
B111-02 to Upstream End	578 PN, 577 RQ	Manmade Earthen Channel Section	6,865	
B111-06 to Beltway 8	577 QP	No channel--stormsewer outfalls `into realigned B104-04	4,275	
B111-01-00				
B111-00 to Private Road	578 Q	Manmade Earthen Channel Section	797	
Private Road to Upstream End	578 Q	Manmade Earthen Channel Section	921	
B111-02-00				
B111-00 to Genoa Red Bluff Road	578 K	Manmade Earthen Channel Section	1,749	
B111-04-00				
B104-04 to upstream end	577 Q	No channel--Replaced by storm sewer	873	
B111-05-00				
B104-04 to Genoa Red Bluff Road	577 Q	No channel--Replaced by storm sewer	1,348	
B111-06-00				
Beltway 8 to Upstream End	577 L	Manmade Concrete Lined Channel Section	1,774	
B112-00-00 (Willowsprings Bayou)				
B100-00 to B112-01	578 LG	Natural Earthen Channel Section	1,314	
B112-01 to B112-05	578 G	Natural Earthen Channel Section	4,160	
B115-05 to Chattanooga Street	578 GCD	Natural Earthen Channel Section	2,249	
Chattanooga Street to B112-02	578 D	Natural Earthen Channel Section	1,840	
B112-02 to Spencer Highway	578 D, 538 Z	Concrete Lined Natural Channel Section	1,315	
Spencer Highway to B112-03	538 Z	Manmade Concrete Lined Channel Section	4,304	
B112-03 to B112-04	538 ZV	Manmade Concrete Lined Channel Section	1,330	
B112-04 to Luella Avenue	538 U	Manmade Concrete Lined Channel Section	1,189	
Luella Ave. to Pasadena Blvd.	538 U	Manmade Concrete Lined Channel Section	1,403	
Pasadena Blvd. to Eileen Street	538 U	Manmade Concrete Lined Channel Section	1,570	
Eileen Street to B112-06	538 U	Manmade Concrete Lined Channel Section	686	
B112-06 to Center Street	538 UT	Manmade Concrete Lined Channel Section	1,230	

Reach/Location	Key Map	Description of Channel	Length (Ft.)	Detention Acreage
B112-01-00				
B112-00 to Fairmont Parkway	578 G	Manmade earthen roadside ditch in Red Bluff Road right-of-way.	3,709	
B112-02-00				
B112-00 to Plantation Street	578 D	Manmade Concrete Lined Channel Section	1,822	
Plantation to Canada Street	578 D	Manmade Earthen Channel Section	692	
Canada Street to Spencer Hwy	578 D, 538Z	Manmade Earthen Channel Section	1,529	
Spencer Hwy to south side B512-01	539 W	Manmade Earthen Channel Section	2,114	
Through B512-01	539 W	Manmade Earthen Channel Section	2,081	
North side B512-01 to Pasadena Blvd.	539 WS	Manmade Earthen Channel Section	1,910	
Pasadena Blvd. to North P Street	539 WSN	Manmade Earthen Channel Section	1,875	
North P Street to Upstream End	539 NJ	Manmade Earthen Channel Section	5,599	
B112-03-00				
B112-00 to B112-03-01	538 ZYX	Manmade Concrete Lined Channel Section	1,466	
B112-03-01 to Center Street	538 ZYX	Manmade Concrete Lined Channel Section	3,011	
B112-03-01				
B112-03 to East Lambuth Lane	538 Y	Manmade Concrete Lined Channel Section	1,330	
East Lambuth Lane to Upstream End	638 Y	Manmade Concrete Lined Channel Section	1,427	
B112-04-00				
B112-00 to West Pasadena Blvd.	538 V	Manmade Concrete Lined Channel Section	953	
West Pasadena Blvd. to East P Street	538 VU	Manmade Concrete Lined Channel Section	2,314	
East P Street to Upstream End	538 Q	Manmade Concrete Lined Channel Section	2,816	
B112-05-00				
B112-00 to Cunningham Dr.	578 G	Manmade earthen roadside ditch in Fairmont Parkway right-of-way.	2,071	
Cunningham Dr. to Center Street	578 CB	Manmade Earthen Channel Section	4,414	


PHOTO BY STEPHAN MYERS

Reach/Location	Key Map	Description of Channel	Length (Ft.)	Detention Acreage
B112-06-00				
B112-00 to Avenue P	538 U	Manmade Earthen Channel Section	984	
Avenue P to San Augustine	538 Q	Manmade Earthen Channel Section	1,869	
San Augustine to X Street	538 Q	Manmade Earthen Channel Section	2,272	
B113-00-00				
B100-00 to Jana Lane	578 LKE	Manmade Earthen Channel Section	8,671	
Jana to B113-01	578 E, 577 M	Manmade Earthen Channel Section	3,179	
B113-01 to Beltway 8	577 ML	Manmade Earthen Channel Section	4,474	
Beltway 8 to B113-03	577L	Manmade Earthen Channel Section	1,855	
B113-01-00				
B113-00 to upstream end	577 M	No channel--Replaced by storm sewer	1,931	
B113-03-00				
B113-03 to upstream end	577 KF	No channel--Replaced by storm sewer	4,871	
B114-00-00				
B100-00 to Spencer Highway	578 A, 538 W	Manmade Earthen Channel Section	1,043	
Spencer Highway to Red Bluff Road	538 W	Manmade Earthen Channel Section	2,025	
Red Bluff Road to Glenwood Avenue	538 X	Manmade Earthen Channel Section	914	
Glenwood Avenue to B114-02	538 XT	Manmade Earthen Channel Section	3,587	
B114-01-00				
B114-00 to Red Bluff Road	538 TS	Manmade Earthen Channel Section	3,329	
B114-02-00				
B114-00 to upstream end	538 T	Manmade Earthen Channel Section	682	
B115-00-00				
B100-00 to Jana Lane	578 A	Natural Earthen Channel Section	2,735	
Jana Lane to B115-01	578 A, 577 D		2,861	

Reach/Location	Key Map	Description of Channel	Length (Ft.)	Detention Acreage
B115-01 to B115-03	577 D		627	
B115-03 to Beltway 8	577 D		1,967	
Beltway 8 to B115-02	577 DC	Manmade Earthen Channel Section	1,913	
B115-02 to Upstream End	577 G	Concrete Lined Manmade Channel Section	758	
B115-01-00				
B115-00 to Beltway 8	577 D	Manmade Earthen Channel Section	1,929	
Beltway 8 to Pansy Street	577 DC	Concrete lined channel adjacent to Old Vista in roadway right-of-way	2,169	
Pansy to Crepe Myrtle Street	577 C	Manmade Earthen Channel Section	3,105	
Crepe Myrtle Street to Spencer Highway	577 C	No channel--Replaced by storm sewer	1,794	
B115-02-00				
B115-00 to Pansy Street	577 G	Manmade Earthen Channel Section	763	
Pansy Street to Colombia Drive	577 G	Manmade Earthen Channel Section	2,729	
Colombia Drive to Upstream End	577 C	Manmade Earthen Channel Section	2,713	
B115-03-00				
B115-00 to Pineneedle Street	577 D	Manmade Earthen Channel Section	869	
B116-00-00				
B100-00 to Heathfield Street	578 FE	Manmade Earthen Channel Section	3,290	
B117-00-00	577 D, 537 Z	No longer a ditch, within B500-01 basin.	1,473	
B204-04-00				
B104-00 to B104-04	618 A, 578 W	Manmade Earthen Channel Section	1,442	
B500-01-00 (Spencer Highway Basin)				
On B100-00 d/s of Spencer Highway	537 Z, 577 D			43 acre site
B500-02-00 (Fairmont Parkway Basin)				
On B100-00 u/s Fairmont Parkway	578 BF			45 acre site
B500-04-00 (Red Bluff Road Basin)				
On B100-00 at confluence w/ B114-00	538 W, 578 A			85 acre site
B504-01-00				
On B104-04 d/s Ellington Field	577 V, 578 S			36 acres
B504-02-00				
On B104-04 u/s Clear Lake City Blvd.	578 W			
B504-03-00				
On Clear Lake City Blvd at El Dorado	578 X			16 acres
B504-04-00				
On B104-00 near Space Center Blvd.	617 D			18 acres
B512-01-00 (Underwood Road Basin)				
On B112-02 u/s Spencer Highway	538 Z, 539 W			80 acre site
B513-01-00				
On B113-00 at Baywood Subd.	578 JK	Developer basin in Baywood Subdivision.		
B513-02-00 (Baywood Basin)				
On B100 at confluence w/ B113-00	578 LK			135 acre site
B513-03-00 (Anthony Road Basin)				
On B113-00 d/s Beltway 8	577 LM			125 acre site
B516-01-00				

Appendix I. Existing Water Quality Outreach Efforts

Water Quality Promotional Materials

- Armand Bayou Watershed roadside signs
  Houston-Galveston Area Council will place roadside watershed signs in the area. The basic sign design approved, funds were made available and sites for sign placement were chosen.
- Armand Bayou Watershed brochure
  Tri-fold brochure highlighting the watershed and some of its more prominent features and threats. Online at: http://www.h-gac.com/ (Type "Armand Bayou" into search box at upper right, should be the first link that comes up, but check to make sure it has 8818 in name. Opens very slowly.)
- Loop trail brochure
  Self-guided driving trail in and around Galveston Bay. The Galveston Bay Foundation received a grant from the Galveston Bay Estuary Program to develop a brochure of a driving self-tour of the many wonders of the Galveston Bay Estuary. (http://galvbay.org/)
- "Clean Water Clear Choice"
  Extensive outreach campaign, complete with logo, canvas bags, folders with pamphlets, magnets, etc. (http://www.cleanwaterclearchoice.org/)
- "Pasadena, Coastal City"
  Series of 12 x 30 minute videos highlighting water quality and Armand Bayou, airing monthly on local access cable TV; available to other cities for use as well. (http://www.ci.pasadena.tx.us/news.htm#TV62)
- No Dumping video
  Ten-minute video, volunteers take to 3rd to 5th grade classes.
- Construction fact sheet (pending)
  One-page fact sheet, for building permit applicants.
- Construction Site Best Management Practices manual (pending)
  Developed by a local Construction BMP Alliance. Being printed by Texas Cooperative Extension/Texas Sea Grant on a grant form the Galveston Bay Estuary Program (www.urban-nature.org)
- Landscape regulation / education
  Code enforcement officers stop landscapers and yard maintenance personnel when they see them blowing grass clippings into the curb drains.
- WaterSmart Landscaping brochures
  Brochures that explain the benefits – both environmental and personal – of proper plant selection and maintenance.
  http://www.urban-nature.org/publications/pef/WS-organicLawnCare.pdf
  http://www.urban-nature.org/publications/pef/WS-WatersmartBrochure.pdf
- Children's art calendar
  Fifth graders artistically incorporate important Bay facts and dates in a popular calendar distributed to area residents, decision-makers and supporters.
- TCEQ water quality programs, efforts, and activities
  http://www.tceq.state.tx.us/AC/nav/eq/eq_water.html
  Refer to TCEQ publications list: http://www.tnrcc.state.tx.us/admin/topdoc/ or http://www.tnrcc.state.tx.us/cgi-bin/exec/publications.pl
- Websites, newsletters, etc.
  Most organizations have websites with a wealth of information available. Organizations with members (such as nonprofits and homeowners' associations), municipalities, and others, such as water districts, have newsletters that are mailed out – and often posted online.
- Teacher Tool Kit - http://www.tpwd.state.tx.us/edu/teacher.phtml
- Wildlife Posters and Fact Sheets - http://www.tpwd.state.tx.us/edu/posters.phtml

Workshops and Classroom Activities about Water Quality and Watersheds

- Master Naturalists
  Intensive several-month week training educates people about the ecology of the area and then creates a network of volunteers for various ecological restoration projects.
  http://www.tpwd.state.tx.us/nature/volunteer/txmasnat/
- Master Gardeners
  Intensive several-month training educates people about the proper planting and care of landscapes and yards. http://aggie-horticulture.tamu.edu/mastergd/mg.html
- Collaborative education workshop (pending)

The groups are working to coordinate awareness and distribution of water quality and stormwater educational materials.

- Water-related eco-classes
  Classes for students from K-12 (depending on course): Water Water Everywhere, Night / dawn/ sunset boat rides, Night hikes, Pond Pal classes, Bayou Studies, EcoCamp, self-guided trail with activity packets, Nature Discovery Classes, etc.—may include dipnet, seine, microscope, talks from staff/volunteers, etc.

- Bay Ambassadors
  Galveston Bay Foundation trains volunteers speak to students at their schools to talk about water quality and relationship to Galveston Bay. (ww.gbf.org)
- "Estuaries Live"
  25 September 2003, out of ABNC—Students and educators from around the country log in for live interaction with experts on estuaries, watersheds, and water quality. (http://www.estuarylive.org/)
- WaterSmart Landscaping Workshop
  One-day workshop and plant sale, offering a multitude of talks about various topics related to smart gardening. (http://www.watersmart.cc/)
- Galveston Bay Yards and Neighbors Program
  Community based education program educates homeowners on "Bay Friendly" home and lawn care practices which help reduce excess use of potential non-point source pollutants that may end up in Galveston Bay. (http://aggie-horticulture.tamu.edu/galveston/galveston_bay_yards_&_neighbors.htm)
- San Jacinto Marsh Restoration Project
  The San Jacinto Battleground State Historical Park preserve is the oldest and most visited state park in Texas and the site of the Marsh Restoration Project. It serves as a centerpiece of natural history training for teachers of K - 6 children. (http://www.eih.uh.edu/education/sjmp.htm)
- Science of Galveston Bay
  Interactive lesson plans show teachers and representatives of local parks and recreation departments how to integrate information about the Bay into their curricula and programs.
- Brown bag lunch lectures
  The Environmental Institute of Houston offers bring-your-own lunch lectures, by a variety of guest speakers, about local environmental issues.
- Citizens' Advisory Panels (CAPs) / Citizens' Advisory Councils (CACs)
  Created to encourage dialogue between chemical plant owners/operators and local neighborhood representatives, CAPs and CACs generally discuss local issues of concern, including environmental threats.
- Hunter, Boater and Angler Education
  Hunter education teaches hunting safety, skills and responsibility. The Texas Boater Education Program stresses boating safety and responsibility. Angling instructors provide several levels of angler training.
- Outdoor Kids
  Outdoor Kids is a self-paced program encouraging young people to experience firsthand the natural, cultural and recreational resources of Texas under the guidance of an adult leader--for instance, a Scout troop leader, a teacher, or a parent.
- Project Wild
  Project WILD/Aquatic WILD is 'Wildlife in Learning Design" - a Kindergarten - 12th grade environmental and conservation education program emphasizing awareness, appreciation and understanding of wildlife and natural resources.
- Community Outdoor Outreach Program
  Builds relationships with non-traditional constituencies who have been underrepresented in Texas Parks & Wildlife activities and programs
- Master Naturalists
  Intensive several-month training educates people about the ecology of the area and then creates a network of volunteers for various ecological restoration projects. (http://www.tpwd.state.tx.us/nature/volunteer/txmasnat/)
- Texas Nature Trackers
  Texas Nature Trackers, associated with the Texas Master Naturalist Program, is a citizen science monitoring effort designed to involve volunteers of all ages and interest levels in gathering scientific data on species of concern in Texas through experiential learning.
- Teacher Tool Kit (http://www.tpwd.state.tx.us/edu/teacher.phtml)
- Wildlife Posters and Fact Sheets (http://www.tpwd.state.tx.us/edu/posters.phtml)
- Becoming an Outdoors Woman
  Provides an atmosphere where women feel comfortable learning new skills associated with hunting, fishing, and other outdoor activities, in a supportive and non-threatening environment.
- Wildscapes
  Texas Wildscapes is a habitat restoration plan for rural and urban areas. Texas Wildscapes are small habitats that provide the essential ingredients for a variety of wildlife-food, water, shelter, and space. This is done by planting and maintaining native vegetation, installing birdbaths and ponds and creating structure. http://www.tpwd.state.tx.us/nature/wildscapes/
- Private Lands and Habitat Enhancement
  The goal of the Private Lands and Habitat Program is to provide expertise to land managers in the preservation and development of wildlife habitat and the proper management of the various wildlife populations which utilize that habitat. (http://www.tpwd.state.tx.us/conserve/private_lands/)
- Landowner Incentive Program
- Incentive programs to assist private landowners in protecting and managing rare species can have a direct and positive impact on their conservation. It is the goal of this program to provide financial incentives that encourage landowners to help conserve rare species. (http://www.tpwd.state.tx.us/conserve/lip/)

Appendix J. Water Quality Outreach Efforts, by Jurisdiction/Organization

This is a list of many, but not all, of the water-related outreach provided by organizations serving the Armand Bayou area.

TCEQ

- TCEQ water quality programs, efforts, and activities—Lead organization: TCEQ (http://www.tceq.state.tx.us/AC/nav/eq/eq_water.html)

GBEP

- Model Phase II Storm Water Management Program
  Manual containing a model storm water management program for use by entities subject to Phase II of the Storm Water regulations. (http://www.gbep.state.tx.us)
- "Estuary Live"
  25 September 2003—Students and educators from around the country log in for live interaction with experts on estuaries, watersheds, and water quality. (http://www.estuarylive.org)

GBIC

- Records Collection
  With funding from both TCEQ and TGLO, maintains a collection of documents, maps, and electronic records of activities within Galveston Bay.
- Bibliography
  Most documents in this appendix are held by GBIC, and can be located by using the Galveston Bay Bibliography (http://gbic.tamug.edu.icx.html), Materials are available for review in-house and by request for inter-library lending.

TPWD

- See http://www.tpwd.state.tx.us/edu/
- See http://www.tpwd.state.tx.us/conserve/
- See http://www.tpwd.state.tx.us/grants/
- **Hunter, Boater and Angler Education**
  Hunter education teaches hunting safety, skills and responsibility. The Texas Boater Education Program stresses boating safety and responsibility. Angling instructors provide several levels of angler training.
- **Outdoor Kids**
  Outdoor Kids is a self-paced program encouraging young people to experience firsthand the natural, cultural and recreational resources of Texas under the guidance of an adult leader--for instance, a Scout troop leader, a teacher, or a parent.
- **Project Wild**
  Project WILD/Aquatic WILD is 'Wildlife in Learning Design" - a Kindergarten - 12th grade environmental and conservation education program emphasizing awareness, appreciation and understanding of wildlife and natural resources.
- **Community Outdoor Outreach Program**
  Builds relationships with non-traditional constituencies who have been underrepresented in Texas Parks & Wildlife activities and programs
- **Master Naturalists**
  Intensive several-month training educates people about the ecology of the area and then creates a network of volunteers for various ecological restoration projects. http://www.tpwd.state.tx.us/nature/volunteer/txmasnat/.
- **Texas Nature Trackers**
  Texas Nature Trackers, associated with the Texas Master Naturalist Program, is a citizen science monitoring effort designed to involve volunteers of all ages and interest levels in gathering scientific data on species of concern in Texas through experiential learning.
- **Teacher Tool Kit** (http://www.tpwd.state.tx.us/edu/teacher.phtml)
- **Wildlife Posters and Fact Sheets** (http://www.tpwd.state.tx.us/edu/posters.phtml)
- **Becoming an Outdoors Woman**
  Provides an atmosphere where women feel comfortable learning new skills associated with hunting, fishing, and other outdoor activities, in a supportive and non-threatening environment.
- **Wildscapes**
  Texas Wildscapes is a habitat restoration plan for rural and urban areas. Texas Wildscapes are small habitats that provide the essential ingredients for a variety of wildlife-food, water, shelter, and space. This is done by planting and maintaining native vegetation, installing birdbaths and ponds and creating structure. (http://www.tpwd.state.tx.us/nature/wildscapes/)
- **Private Lands and Habitat Enhancement**
  The goal of the Private Lands and Habitat Program is to provide expertise to land managers in the preservation and development of wildlife habitat and the proper management of the various wildlife populations that utilize

that habitat. (http://www.tpwd.state.tx.us/conserve/private_lands/)

- **Landowner Incentive Program**
  Incentive programs to assist private landowners in protecting and managing rare species can have a direct and positive impact on their conservation. It is the goal of this program to provide financial incentives that encourage landowners to help conserve rare species. (http://www.tpwd.state.tx.us/conserve/lip/)

HGAC

- **Armand Bayou watershed road signs**
  The basic sign design approved, funds were made available and sites for sign placement were chosen.
- **Armand Bayou watershed brochure**
  Tri-fold brochure highlighting the basin and its more prominent features and threats. (http://www.h-gac.com/NR/rdonlyres/e572zaazuvi2mxyfaltdrfzrqpq6evscrw5myyjdp5wdku5ry54dk5j6cui5lsxvkwnw2wkmb5blt3yclkzwmyic6ka/ArmBay WS08818.pdf)
- **Texas Watch**
  Volunteers trained to take water quality monitoring data and report it regularly; data compiled and available via online database.

TCE / TSG

- **Master Naturalists**
  Intensive several-month training educates people about the ecology of the area and then creates a network of volunteers for various ecological restoration projects.
  (http://www.tpwd.state.tx.us/nature/volunteer/txmasnat/)
- **Master Gardeners**
  Intensive several-month training educates people about the proper planting and care of landscapes and yards.
  (http://aggie-horticulture.tamu.edu/mastergd/mg.html)
- **Galveston Bay Yards and Neighbors Program**
  Community based education program educates homeowners on "Bay Friendly" home and lawn care practices which help reduce excess use of potential non-point source pollutants that may end up in Galveston Bay.

TCWP

- **Armand Bayou Watershed Working Group**
  Citizens, businesses, and governmental representatives are all invited to participate in the Working Group and its activities to improve and maintain the health of the Armand Bayou watershed. (http://www.ArmandBayou.org)
- **WaterSmart landscaping**
  Teaching, demonstrating, and encouraging landscaping plants selected for their water and maintenance requirements. Brochures that explain the benefits—both environmental and personal—of proper plant selection and maintenance.
  (http://www.urban-nature.org/publications/pdf/WS-organicLawnCare.pdf)
  (http://www.urban-nature.org/publications/pdf/WS-WatersmartBrochure.pdf)

Harris County

- **"Clean Water Clear Choice"**
  Houston and Harris County, both Phase I entities, joined forces to create this extensive outreach campaign, through television, radio, and print media logo, canvas bags, folders with pamphlets, magnets, etc. (http://www.cleanwaterclearchoice.org/)
- **Collaborative education workshop (pending)**
  The groups are working to coordinate awareness and distribution of water quality and stormwater educational materials.

Deer Park

- **Interactive web site**
  Citizens can observe news worthy items and report anomalies for City investigation. (http://www.ci.deer-park.tx.us/)
- **Quarterly City newsletter**
  Activity opportunities, mailed to each residential address listed in the City Limits for a water meter; also available through City Hall and the Community Center.
- **Phase II Stormwater Program (pending)**
  In process of developing Stormwater Management program.
- **Recycling program**
  Receptacles and/or regularly scheduled neighborhood collection are provided for residents for the disposal of waste oils, as well as recycling bins for plastic, glass, paper waste, etc.
- **Household hazardous waste collection**
  Annual Household Hazardous Waste Day observance provides opportunities to properly dispose of / recycle these products.
- **Used motor oil collection**
  City provides neighborhood collection of used motor oil and filters for recycling twice a week.
- **New construction regulation / education**
  Building Inspectors require silt fencing at all job sites to help prevent dirt, sand and other debris from entering storm drains.
- **Landscape regulation / education**
  Code enforcement officers stop landscapers and yard care people when they see them blowing grass clippings into the curb drains.

Houston

- **"Clean Water Clear Choice"**
  Houston and Harris County, both Phase I entities, joined forces to create this extensive outreach campaign, through television, radio, and print media logo, canvas bags, folders with pamphlets, magnets, etc. (http://www.cleanwaterclearchoice.org/)
- **Collaborative education workshop (pending)**
  The groups are working to coordinate awareness and distribution of water quality and stormwater educational materials.
- **WaterWise landscaping**
  Booklet on water-conserving techniques for the homeowner.

La Porte

- **Phase II Stormwater Program (pending)**
  In process of developing Storm Water Management program.
- **Recycling program**
  Receptacles are provided for residents for the disposal of waste oils as well as recycling bins for plastic, glass, paper waste, etc.
- **Pretreatment program- commercial vehicle equipment washing**
  City does not allow unauthorized discharges to ditches and/or storm from washing activities at commercial facilities. Wash water is directed to sanitary sewer system.
- **Interactive web site**
  Citizens can observe news worth items and report anomalies for City investigation. (http://www.ci.la-porte.tx.us)
- **New construction regulation / education**
  Building Inspectors require silt fencing at all job sites to help prevent dirt, sand and other debris from entering storm drains.
- **Landscaped regulation / education**
  Code Enforcement prevents landscapers and yard care crews from blowing grass clippings into the streets and drains if seen.
- **Community service**
  Community Service hours are used to clean streets, parks curbs, ditches, and the beach areas.
- **Ditch cleaning**
  City employees regularly mow and clean debris out of ditches to prevent solids and pollutants from entering waterways and to improve drainage.

Pasadena

- **"Pasadena, Coastal City"**
  Series of 12 x 30 minute videos highlighting water quality and Armand Bayou, airing monthly on local access cable tv; available to other cities for use as well.
- **Phase I Stormwater Program**
  Currently in its second iteration of the 5-year stormwater management plan.
- **No Dumping video**
  Ten-minute video, volunteers take to 3-5th grade classes.
- **Stormwater marker buttons**
  Students affix these markers to storm drains in neighborhood, alerting citizens that the water flows directly—untreated—to the bayous and bay.
- **Ditch cleaning and associated outreach**
  In conjunction with the "ditch" clearing effort, city employees place door hangers on each house adjacent to a cleaned ditch, informing folks that the water flows to Galveston Bay, that they are the stewards, and asking them to look out for pollutants.
- **Construction fact sheet (pending)**
  One-page fact sheet, for building permit applicants.
- **Landscape regulation / education**
  Code enforcement officers stop landscapers and yard care people when they see them blowing grass clippings into the curb drains.
- **Household hazardous waste (HHW) pick-up**
  City curb-side pick-up of HHW; residents call city to schedule pick-up. Keeps HHW out of landfills and waterways.
- **Clean Streets (community service)**
  Community service hours are used to clean streets, curbs, and roadside ditches of "floatables" and other trash.
- **City newsletter**
  Newsletter, providing activity opporunities, is distributed to residents. Copies are available through City Hall and the Community Center.
- **Recycling**
  Receptacles and scheduled pick-up provided by the city. By collecting and reusing used materials, the amount of waste materials that go into the landfills, streets, sewers, and waterways.

GBF

- **Armand Bayou watershed road signs**
  Basic sign design approved, funds were available, sites for sign placement chosen.
- **Drive and Discover Trail**
  Self-guided driving trail in and around Galveston Bay.
- **Marsh Mania**
  Volunteers replant native marsh plants to reclaim lost marsh lands in the Galveston Bay region.

- **Trash Bash**
  Volunteer opportunity to get out and clean the rivers/bayous/bay/lakes and floodways of trash and debris. (http://www.trashbash.org/)
- **Science of Galveston Bay**
  Interactive workshops show teachers and representatives of local parks and recreation departments how to integrate information about the Bay into their curricula and programs.
- **Bay Ambassadors**
  Volunteers speak to students at their schools to talk about water quality.
- **Armand Bayou monitors (pending)**
  Group wants to watch Armand Bayou specifically, monitor survival and growth of Marsh Mania replanting efforts.
- **Children's art calendar**
  Fifth graders artistically incorporate important Bay facts and dates in a popular calendar distributed to area residents, decision-makers. and supporters.
- **Galveston Bay Expeditions**
  Participants walk, paddle in canoes, or ride aboard Bay Ranger to explore one of several sites around the Bay, learning about habitat, uses and history.
- **Newsletter**
  Quarterly newsletter, providing activity opportunities, is mailed to members, supporters, and local decision-makers.

ABNC

- **Water-related eco-classes**
  Classes for students from K-12 (depending on course):
  - Water Water Everywhere
  - Nature Discovery Classes
  - Night / dawn / sunset boat rides
  - Night hikes
  - Pond Pal classes
  - Bayou Studies
  - EcoCamp
  - Self-guided trail with activity packets

  May include dipnet, seine, microscope, talks from staff/volunteers, etc.
- **Marsh Mania**
  Volunteers replant native marsh plants to reclaim lost marsh lands in the Galveston Bay region.
- **Trash Bash**
  Volunteer opportunity to get out and clean the rivers/bayous/bay/lakes and floodways of trash and debris.

EIH

- **Texas State Envirothon**
  The Envirothon is the largest high school environmental competition, open to any high school student (grades 9 - 12). The Envirothon is an integrated educational experience that will enhance your students' knowledge and environmental literacy.
  (http://www.envirothon.org)
- **Schoolyard habitats**
  Schools build backyard habitat sites and learn how the various animals use them. These experiences also provide many resources to teachers who want to use the outdoors as a context for learning.
- **Brown bag lunch lectures**
  Bring-your-own lunch lectures, by a variety of guest speakers, about local environmental issues.
- **San Jacinto marsh project**
  The San Jacinto Battleground State Historical Park preserve is the oldest and most visited state park in Texas and the site of the Marsh Restoration Project. It serves as a centerpiece of natural history training for teachers of K - 6 children.
- (http://www.eih.uh.edu/education/workshops.htm)

Other

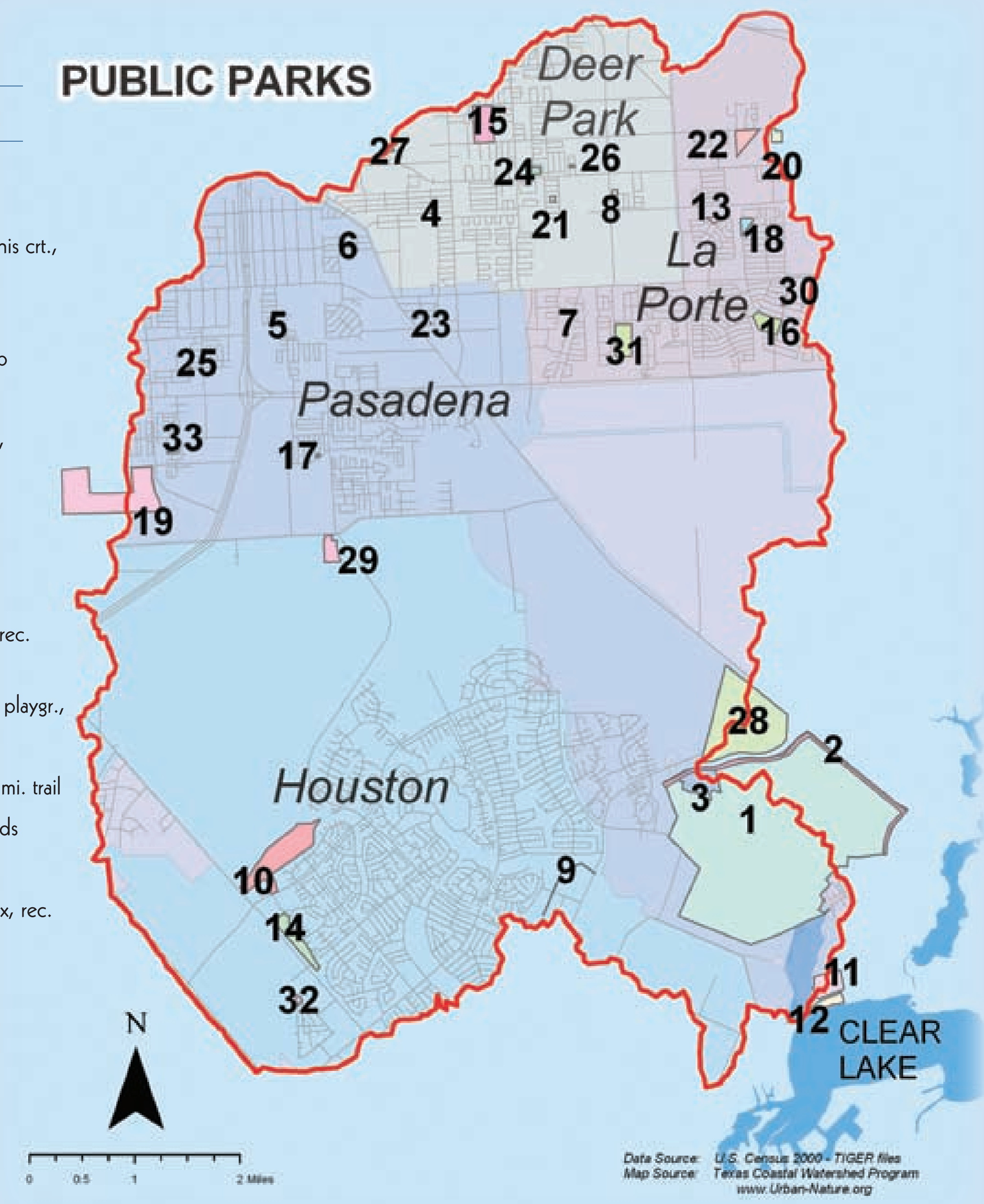
- **Community Advisory Panels (CAPs) / Citizens' Advisory Councils (CACs)**
  Created to encourage dialogue between chemical plant owners/operators and local neighborhood representatives, CAPs and CACs generally discuss local issues of concern, including environmental threats.

PHOTO © CLIFF MEINHARDT

Appendix K. Public Parks in the Watershed

Parks	Park Name	Map No.	Jurisdiction	Address	City	Acres
Special Use	Armand Bayou Nature Preserve	**1**	Harris Co.	8500 Bay Area Blvd.	Pasadena	2293
Linear	Bay Area Hike & Bike Trail	**2**	Harris Co.			
Community	Bay Area Park	**3**	Harris Co.	7500 Bay Area Blvd.	Pasadena	53
N/A	Bayou Bend Park	**4**	Deer Park		Deer Park	8
Neighborhood	Bliss Meadows Park	**5**	Pasadena	5900 S. Meadow Dr.	Pasadena	4
Pocket	Bramley Park	**6**	Pasadena	6500 Bramley	Pasadena	2
Community	Brookglen Park	**7**	LaPorte	3324 Somerton	LaPorte	4
N/A	Brownwind Park	**8**	Deer Park	3901 Brownwind	Deer Park	3
Linear	Clear Lake Hike & Bike Trail	**9**	Houston	Bay Area Blvd./ El Dorado	Houston	
Regional	Clear Lake (Sylvan Rodriquez)	**10**	Houston	1201 Clear Lake Blvd.	Houston	112
Community	Clear Lake Park North	**11**	Harris Co.	5000 NASA Pkwy	Taylor Lake Village	43
Neighborhood	Clear Lake Park South	**12**	Harris Co.	5001 NASA Pkwy	Taylor Lake Village	16
Neighborhood	Creekmont	**13**	LaPorte	700 Willow Creek	LaPorte	3
Community	Dads Club Sports Park	**14**	Harris Co.	14500 Village Evergreen	Houston	35
N/A	Dow Park	**15**	Deer Park	610 E. San Augustine	Deer Park	40
Regional	Fairmont Park	**16**	LaPorte	3540 Farrington	LaPorte	15
Pocket	Ghana Play Lot	**17**	Pasadena	6146 Ghana	Pasadena	1
Neighborhood	Glen Meadows Park	**18**	LaPorte	801 Valley Brook	LaPorte	8
Neighborhood	Holly Bay Court	**19**	Pasadena	7102 Crenshaw	Pasadena	11
Regional	Lomax Park	**20**	LaPorte	1508 Lomax School Rd.	LaPorte	9
N/A	Monroe Park	**21**	Deer Park	1560 Monroe St.	Deer Park	2
Regional	Northwest Park	**22**	LaPorte	10210 N. P St.	LaPorte	20
Pocket	Olson Park	**23**	Pasadena	7300 Olson Rd.	Pasadena	< 1
N/A	Park Meadows	**24**	Deer Park	1414 S. Parkway	Deer Park	6
Pocket	Parkgate North Park	**25**	Pasadena	3900 Zuni Trail	Pasadena	1
Undeveloped	Parkside Park	**26**	Deer Park	Somerset Ln.	Deer Park	1
N/A	Parkview Park	**27**	Deer Park	1109 Brookhollow	Deer Park	1
Regional	Roy D. "Kipper" Mease Park	**28**	Harris Co.	10700 Red Bluff Rd.	Pasadena	297
Undeveloped	Space Center Blvd. Wetlands	**29**	Harris Co.			24
Undeveloped	Spenwick Park	**30**	LaPorte	19225 Carlow	LaPorte	0.32
Undeveloped	Westside Park	**31**	LaPorte	3600 Canado Rd.	LaPorte	34
Neighborhood	Williams Park	**32**	Houston	15000 McConn St.	Houston	1
Undeveloped	Yellowstone Park	**33**	Pasadena	4800 Yellowstone Dr.	Pasadena	4
						3051.32

Facilities
restrooms, picnic area, nature trails
5.2 mi. trail
restrooms, picnic area, playgr., shltr., tennis crt., soccer field, baseball field, canoe ramp
Not Available
basketball, picnic area, playgr., 1 backstop
playground, backstop, park benches
swimming pool, playgr., 2 baseball fields, sand volleyball court, rec. center
Not Available
1 mi. trail
playgr., pavillion, trail
tennis, 4 soccer fields, 3 baseball fields, rec. center
4 softball fields, 2 baseball fields, tennis, playgr., rec. center
1 baseball field, basketball, playgr., 0.25 mi. trail
restrooms, 6 soccer fields, 6 baseball fields
Not Available
swimming pool, playgr., baseball complex, rec. center, 0.5 mi trail
basketball, picnic area, playgr.
0.5 mi trail, playgr. 4 baseball fields
0.8 mi trail, playgr., restrooms
covered rodeo arena, rec. center
Not Available
6 soccer fields, swimming pool
playgr., park benches
Not Available
playgr., basketball, picnic
undeveloped
Not Available
restrooms, 3 softball fields
undeveloped
undeveloped
undeveloped
indoor pool, rec. center
undeveloped



Appendix L. Planning Criteria Matrix

County (1)	Flood Plain Administrator / Drainage District (2)	Design Manual Used (3)	Flood Plain Resolutions/Ordinances (4)	Policy and Flood Plain Management: Flood Control Master Plan (5)	Storm Sewer Master Plan (6)	NFIP (7)	Detention Policy (8)
Harris	City of Houston	City of Houston	Code of Ordinances: Ch. 19	No	Yes	Yes	Yes
Fort Bend & Brazoria & Harris	City of Pearland	City of Pearland Criteria Manual / Brazoria Drainage District #4	Ordinance 532-2; Resolution R2003-49	Yes		Yes	Yes
Brazoria	City of Brookside Village	Brazoria Drainage District #4	Ordinance 90-3-99	No		Yes	Yes
Galveston & Harris	City of Friendswood	City of Friendswood /Galveston County Consolidation Drainage District	Code of Ordinances: Ch. 34	No	Yes	Yes	Yes
Galveston	City of League City	City of League City	Code of Ordinances: Ch. 50; Ordinance 99-61	Yes	Yes	Yes	No Impact
Harris	City of Webster	City of Houston	Code of Ordinances: Ch. 42	Yes		Yes	Yes
Harris	City of Nassau Bay	City of Houston	Code of Ordinances: Ch. 8	Yes		Yes	No
Harris	City of El Lago		Code of Ordinances: Ch. 7	No		Yes	No
Harris	City of Taylor Lake Village		Ordinances 89-293, 87-260, & 97-386	No		Yes	No
Galveston	City of Clear Lake Shores		Code of Ordinances: Ch. 15.36 & Ch. 15.28	No		Yes	No
Galveston	City of Kemah		Ordinance 11-99	No		Yes	No
Harris	City of Seabrook	Harris County Flood Control District	Code of Ordinances: Ch. 38	No		Yes	No
Harris	City of Shore Acres		Ordinance 2001-18	Yes		Yes	No
Harris	City of Deer Park		Code of Ordinances: Ch. 10; Ordinance No. 2459			Yes	Yes
Harris	City of LaPorte	Public Improvements Criteria Manual (Resolution 99-31) / Harris County Flood Control District	Resolution 99-31; Code of Ordinances: Ch. 94	Yes		Yes	Yes
Harris	City of Pasadena	City of Pasadena (in progress)	Code of Ordinances: Ch. 9; Ordinance 2000-58; Ordinance 95-253; Emergency Management Plan	Yes		Yes	Yes
Fort Bend	Fort Bend County	Fort Bend County Drainage District	Regulations for Floodplain Management	Yes		Yes	Yes
Brazoria	Brazoria County	Brazoria Drainage District No. 4	Building Regulations	Yes		Yes	Yes
Galveston	Galveston County	Subdivision Design Manual	Flood Plain Regulations	Yes		Yes	Yes (1)
Harris	Harris County	Harris County Flood Control District	Regulations for Floodplain Management	Yes		Yes	Yes

(1) if impacts tributary to Clear Creek watershed

Policy and Flood Plain Management, cont'd.								Storm Sewer Design	
County (1)	Flood Plain Administrator (2)	Detention Outfall Storm Frequency (9)	Regional Detention (10)	CRS Rating (11)	Minimum Slab Elev. above 100-yr Flood Levels (12)	Flood Plain Storage Compensation (13)	Conveyance Mitigation (14)	Frequency (15)	Rainfall Source (16)
Harris	City of Houston	100-YR / Storm Sewer Capacity	No	8	12"	Yes	Yes	2-YR	City of Houston
Fort Bend & Brazoria & Harris	City of Pearland	3-, 10-, 100-YR	Yes (2)		12"	Yes	Yes	3-YR	City of Pearland
Brazoria	City of Brookside Village	10- & 100-YR	No		12"	Yes	Yes	3-YR	BDD4
Galveston & Harris	City of Friendswood	5-, 25-, 100-YR	No	5	24"	Yes	Yes	5-YR	TxDOT
Galveston	City of League City	NA	No	9	18"	Yes	Yes	2-YR	City of Houston
Harris	City of Webster	100-YR	No		12"	Yes	Yes	2-YR	City of Houston
Harris	City of Nassau Bay	NA	No	8	24"	Yes	Yes	2-YR	City of Houston
Harris	City of El Lago	NA	No		0"	No	Yes	NA	
Harris	City of Taylor Lake Village	NA	No	8	14' (above sea level)	No	Yes	NA	
Galveston	City of Clear Lake Shores	NA	No		0"	Yes	Yes	NA	
Galveston	City of Kemah	NA	No	5	18"	Yes	Yes	NA	
Harris	City of Seabrook	NA	No	9	0"	Yes	Yes	2-YR	City of Houston
Harris	City of Shore Acres	NA	No		12"	Yes	Yes	NA	
Harris	City of Deer Park	100-YR		9	0"	Yes	Yes		
Harris	City of LaPorte	100-YR	No	8	12"	Yes	Yes	3-YR	City of La Porte
Harris	City of Pasadena	100-YR	No		12"	Yes	Yes	3-YR	City of Pasadena
Fort Bend	Fort Bend County	100-YR	No		12"	Yes	Yes	2-YR	Fort Bend Co.
Brazoria	Brazoria County	10- & 100- YR	Yes		0"	Yes	Yes	3-YR	BDD4
Galveston	Galveston County	100-YR	No		0"	Yes	Yes	2-YR	Galveston Co.
Harris	Harris County	10-, 100-YR	Yes	8 (3)	18"	Yes	Yes	2-YR	City of Houston

(2) City of Pearland sells detention capacity for $7,500/ac-ft.
(3) Unofficial rating

			Policy and Flood Plain Management				
County	Drainage District	Design Manual Used	Flood Plain Resolutions/Ordinances	Flood Control Master Plan	Storm Sewer Master Plan	NFIP	Detention Policy
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fort Bend	Fort Bend County Drainage District	Fort Bend County Drainage District		Yes			Yes
Brazoria	Brazoria Drainage District No. 4	Brazoria Drainage District No. 4		Yes			Yes
Brazoria	Brazoria County Conservation and Reclamation District No. 3	Brazoria County Conservation and Reclamation District No. 3		Yes			Yes
Galveston	Galveston County Consolidation Drainage District	Galveston County Consolidation Yes Drainage District		Yes			
Harris	Harris County Flood Control District	Harris County Flood Control District		No			Yes

		Policy and Flood Plain Management, cont'd.						Storm Sewer Design	
County	Drainage District	Detention Outfall Storm Frequency	Regional Detention	CRS Rating	Minimum Slab above 100-yr Flood Levels	Flood Plain Storage	Conveyance Mitigation	Frequency	Rainfall Source
(1)	(2)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Fort Bend	Fort Bend County Drainage District	100-YR	No		12" (above pending)	Yes	Yes	2-YR	
Brazoria	Brazoria Drainage District No. 4	10- & 100-YR	No		NA	Yes	Yes	3-YR	
Brazoria	Brazoria County Conservation and Reclamation District No. 3	100-YR	Yes		NA	Yes	Yes	5-YR	BDD4
Galveston	Galveston County Consolidation Drainage District	25- & 100-YR	Yes		0"	Yes	Yes	5-YR	
Harris	Harris County Flood Control District	100-YR	Yes		NA	Yes	Yes	2-YR	

Appendix M. Other Resources

A. Habitat

Wetlands Web. Texas Parks and Wildlife Department Website. (http://www.tpwd.state.tx.us/wetlands/)

B. Water Quality

Environmental Inventory of the Armand Bayou Coastal Preserve, March 1991 (Galveston Bay National Estuary Program Publication GBNEP-8) (http://gbep.tamug.edu/gbeppubs/8/gbnep-8.html)

Regulatory Survey for the Armand Bayou Coastal Preserve, March 1991 (Galveston Bay National Estuary Program Publication GBNEP-10) (http://gbep.tamug.edu/gbeppubs/10/gbnep-10.html)

GBNEP-13 (http://gbep.tamug.edu/gbeppubs/13/gbnep-13.html)

Galveston Bay

State of the Bay, 1994 (GBEP) (http://gbep.tamug.edu/gbeppubs/44/gbnep-44.html)

State of the Bay, 2002 (GBEP) (http://gbep.tamug.edu/sobdoc/sob2/sob2page.html)

Galveston Bay Plan (GBEP) (http://gbep.tamug.edu/gbeppubs/49/gbnep-49.html)

The State of Galveston Bay (TCEQ), Fall 2002 (http://www.tnrcc.state.tx.us/admin/topdoc/pd/020/02-04/galvestonbay.html)

Galveston Bay Wetland Inventory Map (USGS) (http://gulfsci.usgs.gov/galveston/index.html)

Harris County

Watershed Bioassessment Project, including links to raw data (HGAC) (http://tx.usgs.gov/hgac/index.html)

Texas

Water Data for Texas (http://tx.waterdata.usgs.gov/nwis)

Draft: Texas 303(d) list, 2002 (TCEQ) (http://www.tnrcc.state.tx.us/water/quality/02_twqmar/02_categories/02_303d.pdf) scroll down to Sections 1113 and 1113A (pg. 30) for Armand Bayou

C. Flooding and Stormwater Management

Harris County Flood Control district: (http://www.hcfcd.org)

D. Public Outreach

Environmental Education Curricula

- Project WET (http://www.projectwet.org/)
- Project Learning Tree (http://www.plt.org/)
- Project WILD, especially Advanced WILD (Aquatics) (http://www.projectwild.org/)
- WET in the City (http://www.wetcity.org/)
- Programs such as North Carolina's Environmental Education Learning Experience (EELE), where each state park develops, produces, and implements its own environmental education curriculum based on the natural resources in and around the park itself.

Selected list of organizations and resources for materials, lessons, and information

EPA's watershed resources: (http://www.epa.gov/owow/)watershed/ (within the EPA's Office of Wetlands, Oceans, and Watersheds: (http://www.epa.gov/owow/); and (http://www.epa.gov/owow/nps/kids/)

OWOW not only provides a network of watershed groups from throughout the nation, but it also contains information on individual watersheds and river basins, establishing collaborative planning groups, upcoming or past events, grants and funding opportunities, and its watershed academy.

Know Your Watershed: (http://www.ctic.purdue.edu/KYW)

Housed at Purdue University, KYW has an extensive website that provides quizzes, fact sheets, basic talking points, technical manuals, a calendar of events, and more for watershed-based education and outreach. In addition it provides extensive networks to other, more established groups.

American Clean Water Foundation: (http://www.acwf.org/)

"Not-for-profit, Washington, DC, based organization that specializes in outreach and education services on clean water issues."

Water Education Federation: (http://www.wef.org/)

WEF provides lesson papers, plans, brochures, pamphlets, sliding informational wheels, and more about water and water-related issues.

American Rivers: (http://www.americanrivers.org/)

"nonprofit conservation organization dedicated to protecting and restoring rivers nationwide."

Rivers Network: (http://www.rivernetwork.org/)

"Helping people understand, preserve, and restore rivers and their watersheds."

Center for Watershed Protection: (http://www.cwp.org/)

A non-profit 501(c)3 corporation, The Center, drawing from its broad experience with watershed groups throughout the country, has services ranging from case studies to consulting services and partnering opportunities, to its own watershed institute.

Envirothon: (http://envirothon.org/)

Shepherded by the National Association of Conservation

Districts in League City, TX, Envirothon highlight aquatics as one of the 5 topics taught to and mastered by middle and high school students.

North American Association of Environmental Educators: (http://www.naaee.org)

"Promoting a healthy, sustainable environment through education."

Council on Environmental Education: (http://www.c-e-e.org/)

Based here in Houston, CEE is a 501(c)3 non-profit educational organization "to provide environmental education programs and services that promote stewardship of the environment and further the capacity of learners to make informed decisions."

Water Stormwater Habitat Education Development (WaterSHED):

(http://fcgov.com/utilities/watershed.php)

This environmental education curriculum in Fort Collins County, Colorado, is funded by 1% of the stormwater utility fee, annual budget ranging from $50-70,000. These funds support a full-time educator/coordinator, produce and distribute materials, and otherwise provide information to the general public.

Know your Watershed Address: (http://www.ee.enr.state.nc.us/EEdocs/ecoadr/ecoadr.htm)

North Carolina established a comprehensive, statewide watershed awareness effort several years ago, combining efforts of the state's Office of Environmental Education, Wildlife Resources Commission, Department of Transportation to increase the citizens' awareness about the watershed in which they live.

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Wetlands
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ARTICLE

Evidence of Surface Connectivity for Texas Gulf Coast Depressional Wetlands

Bradford P. Wilcox · Dex D. Dean · John S. Jacob · Andrew Sipocz

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Abstract Depressional wetlands are distributed throughout the United States and provide many essential ecosystem services. It is important, from both an ecological and a regulatory perspective, to understand the surface water pathways that connect such wetlands to each other and to surrounding water bodies. For many of these wetlands systems, the amount of surface water discharged is poorly quantified. In this paper we report on a 45-month study quantifying the surface discharge characteristics of a wetland on the Texas Gulf of Mexico Coastal Plain. The results of this study indicate that surface runoff, although intermittent, occurred regularly and accounted for more than 17% of watershed precipitation over the 45 months, with annual runoff ranging from 0% to 27%. Runoff typically occurred in precipitation-driven pulses and coincided with increased runoff in adjacent waterways. The detailed results of this study and similar observations from other locations run contrary to the widespread perception that depressional wetlands on the Texas Gulf Coast are hydrologically isolated—which calls into question the regulatory policies governing large tracts of coastal plain wetlands (at least 400,000 ha in Texas alone).

Keywords Forested wetlands · Geographically isolated wetlands · Overland flow · Runoff · Wetland hydrology · Water budget

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Introduction

Wetlands display a continuum of connectivity to surrounding surface waters. Some are strongly connected, such as wetlands in riparian corridors or along coastal areas, while others, such as playa lakes in the Great Plains, have little if any hydrological connection. Classification schemes have been developed to help determine the extent to which wetlands are connected or isolated. However, this has proved to be a challenge, precisely because wetlands in reality display a "continuum of connectivity" (Leibowitz 2003; Leibowitz and Nadeau 2003). Some are strongly connected to the surrounding landscape and others less so, but in fact few are truly isolated.

Traditionally, the term "isolated wetland" has been applied to depressional wetlands that are surrounded by uplands. However, as noted by Tiner (2003b), the term is problematic because it is a "relative term that could be defined from geographic, hydrologic, and ecologic perspectives," and as noted above, few if any wetlands are truly isolated (Leibowitz 2003; Leibowitz and Nadeau 2003). In an effort to achieve more precision, Tiner has proposed the term "*geographically isolated*" as a more useful descriptor of these wetlands. Geographic isolation is much easier to determine than either hydrologic isolation or ecologic isolation. He defines a geographically isolated wetland as "one that is completely surrounded by upland (e.g., hydrophytic plant communities surrounded by terrestrial plant communities or undrained hydric soils surrounded by hydric soils)" (Tiner 2003b).

Wetlands fitting this definition of geographically isolated are often considered hydrologically isolated as well; however, many are in fact connected, via subsurface pathways, with nearby water systems (Tiner 2003b; Whigham and Jordan 2003; Winter and LaBaugh 2003). Notable examples are karst-sinkhole wetlands (Tihansky and Knochenmus 2001), Carolina Bay wetlands (Pyzoha et al. 2008), vernal pools in California (Rains et al. 2006, 2008), and Sandhill wetlands (Winter 1986). In contrast, hydrological connectivity via surface processes (overtopping of wetland depressions), although observed, has seldom actually been measured. Despite the lack of data, surface connectivity is assumed to be relatively uncommon (occurring only in very wet years) and to rarely involve significant amounts of water (Leibowitz 2003). However, surface connectivity via connecting swales has been established in both prairie pothole wetlands (Leibowitz and Vining 2003) and vernal pools in California (Rains et al. 2006, 2008).

Although the definition of geographically isolated wetland is reasonably straightforward and easy to apply, for many situations there has still been some ambiguity in terms of how it has been applied. A case in point is the depressional wetlands along the Texas Gulf Coast. In this region, wetlands that are not directly adjacent to larger water bodies have been classified as geographically isolated (Tiner et al. 2002; Tiner 2003a, b). However, these wetland complexes are clearly interconnected to surrounding waters through sloughs and poorly defined drainage paths that are seasonally wet (Fig. 1). The problem is that the amount of surface runoff through these features is largely unknown (Tiner 2003a) and assumed by many to be insignificant (Sipocz 2005).

Our relatively poor understanding of surface hydrological connections in wetlands that are considered to be geographically isolated underscores the broader issue: the scientific community has probably not provided the wetland regulatory community with sufficient information to credibly support policy-making and jurisdictional decisions. For example, the scientific community urgently needs to carry out research focusing on the fundamental processes of isolated wetlands (Leibowitz and Nadeau 2003)—in particular, the frequency, duration, and amount of flow from wetlands that lack a continuous surface-water connection to navigable waters (Nadeau and Rains 2007). Our lack of knowledge about the nature of runoff generated by these wetlands increases the difficulty of anticipating what will happen if they are

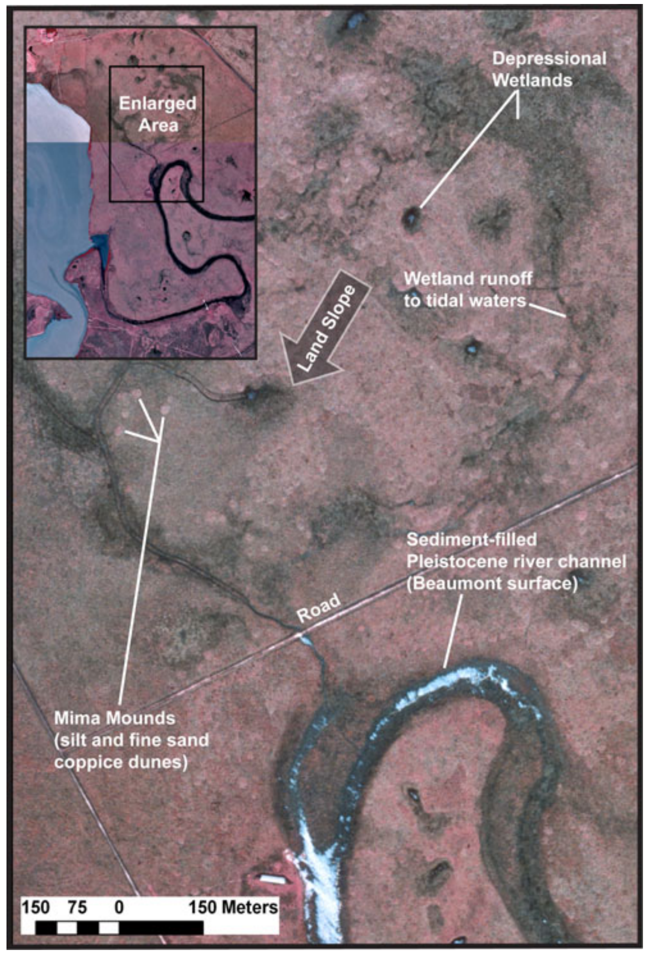

Fig. 1 A color infrared aerial photo highlighting typical features of depressional wetlands on the Texas Gulf Coast. Clearly, many of the wetland depressions are interconnected via intermittently wet swales. This image is of the Lake Austin estuary adjacent to the Matagorda Bay. This area is underlain by the same Beaumont Coastal Terrace geologic formation as the Armand Bayou study site; however, it is located in unforested prairie where wetland and runoff patterns are readily visible from the air. Lighter shaded areas correspond to growing vegetation on drier lands with darker shaded areas to senesced vegetation in wetlands. Open water is blue or white. Three paleo-river tributaries are visible as drainages, with the most recent being well-defined and tidal in its lower reach. Wind-deflated wetland basins similar to the study site are carved from the lighter textured channel and levee soils and overflow into the drainages. A ditch is dug along the length of the western-most paleo-channel in an attempt to drain the wetlands

converted to other land uses. Another important reason for gaining a better understanding of these processes is that surface hydrological connectivity is a key criterion for identifying which wetlands in the United States fall under the regulatory authority of the Clean Water Act (CWA) (Leibowitz et al. 2008).

In this paper, we report the results of a 45-month study quantifying the magnitude and timing of surface drainage or runoff discharged from a depressional wetland complex on the Pleistocene Texas Gulf Coastal

Plain. The objective of this study was to determine the true nature of surface connectivity in these wetlands. A secondary objective was to determine the extent to which urbanization may alter runoff dynamics.

Study Site

The Texas Coastal Plain is a 30,000-km^2 depositional plain located in South Texas along the northwestern side of the Gulf of Mexico. The area is characterized by very poorly drained and seasonally waterlogged soils and a lack of incised channels (Sipocz 2005). Freshwater palustrine wetlands at one time covered more than a third of the landscape (Moulton and Jacob 2000). As of 1992, about 1.3 million hectares of freshwater wetlands remained—some 24% of which were forested wetlands (Moulton et al. 1997). A recent inventory of isolated wetlands in the United States estimated that about 50% of wetlands on the Texas Coastal Plain were geographically isolated (Tiner et al. 2002; Tiner 2003a). Others, however, have argued on the basis of aerial imagery analysis that these wetlands are in fact connected to major waterways via intermittent and generally unmapped channel networks (Jacob and Lopez 2005; Sipocz 2005).

Our study took place in a watershed that encompasses a wetland complex overlying the Beaumont geologic formation,

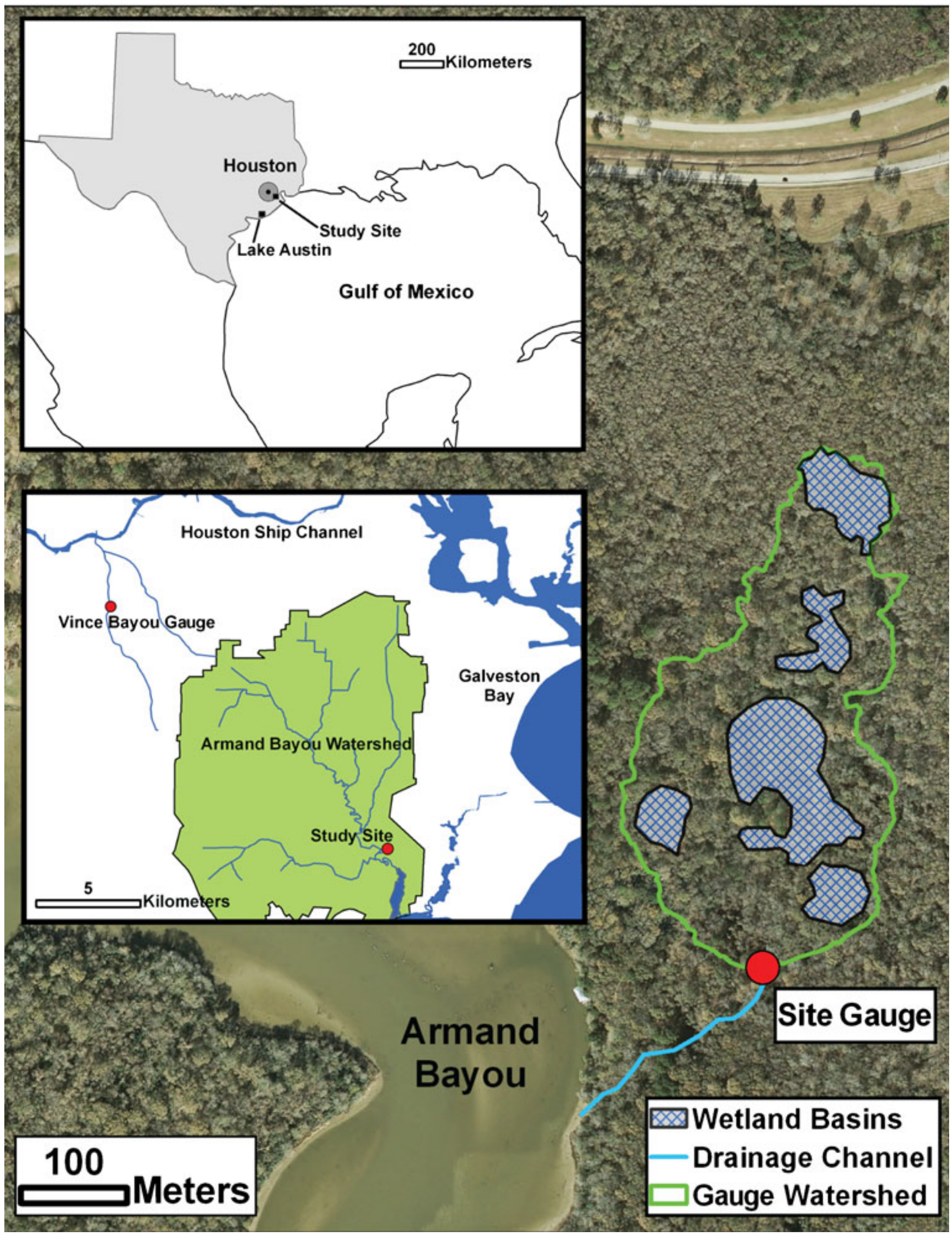

Fig. 2 Location map of the study watershed, showing wetland depressions (hashmarked) and watershed boundary

a Pleistocene-age fluvial-deltaic deposit common on the Texas Coastal Plain (Blum and Aslan 2006). Most of the wetlands on this formation took shape in meander scars or other fluvial features of the ancestral rivers that laid down the formation. The undisturbed Beaumont surface does not typically show strong visible evidence of a naturally integrated drainage system. At first glance, and especially during dry periods, it can be difficult to identify outlets from the wetland depressions. However, closer inspection reveals numerous shallow swales between depressions (Fig.1). The overall pattern is a complex mosaic of depressions, surrounding wetlands, and small non-wetland hillocks (known locally as a pothole–pimple-mound complex) which occurs in both forested and prairie landscapes (Moulton and Jacob 2000; Sipocz 2005).

The study watershed (Fig. 2) is part of a pothole–pimple-mound complex in a riparian forest adjacent to a large prairie. Located in the Armand Bayou Nature Preserve, southeast of Houston, Texas, the watershed is slightly larger than 8 ha (20 ac) and lies just outside the 100-year floodplain of the bayou. About 25% of the watershed consists of wetland depressions having emergent herbaceous vegetation; these depressions are interspersed with transitional flats and forested upland mounds. Average annual rainfall is 1,330 mm (Wheeler 1976). Snowfall is negligible and soil temperatures at a 20-cm depth never drop below 4°C.

The riparian forest is dominated by willow oak (*Quercus phellos*) and swamp red oak (*Quercus pagodafolia*). Chinese tallow (*Triadica sebifera*) is also common and spreading. Emergent species observed in the depressions include swamp smartweed (*Polygonum hydropiperoides*), three-fingered dog shade (*Cynosciadium digitatum)*, sugarcane plume grass (*Saccharum giganteum*), sedges (*Carex* spp.), and palmetto (*Sabal minor*).

The study watershed is mapped as Verland silty clay loam (Fine, smectitic, hyperthermic Chromic Vertic Epiaqualfs) (http://soils.usda.gov/survey/online_surveys/texas/). Our observations suggest most of the soil in the watershed is significantly wetter than what is described for the Verland series. Depressions were not mapped separately in this area, but likely correspond to the Leton series (Fine-silty, siliceous, superactive, hyperthermic Typic Glossaqualfs), which is commonly mapped in similar depressions in this area. The typical profile for a Verland soil is 18 cm of silty

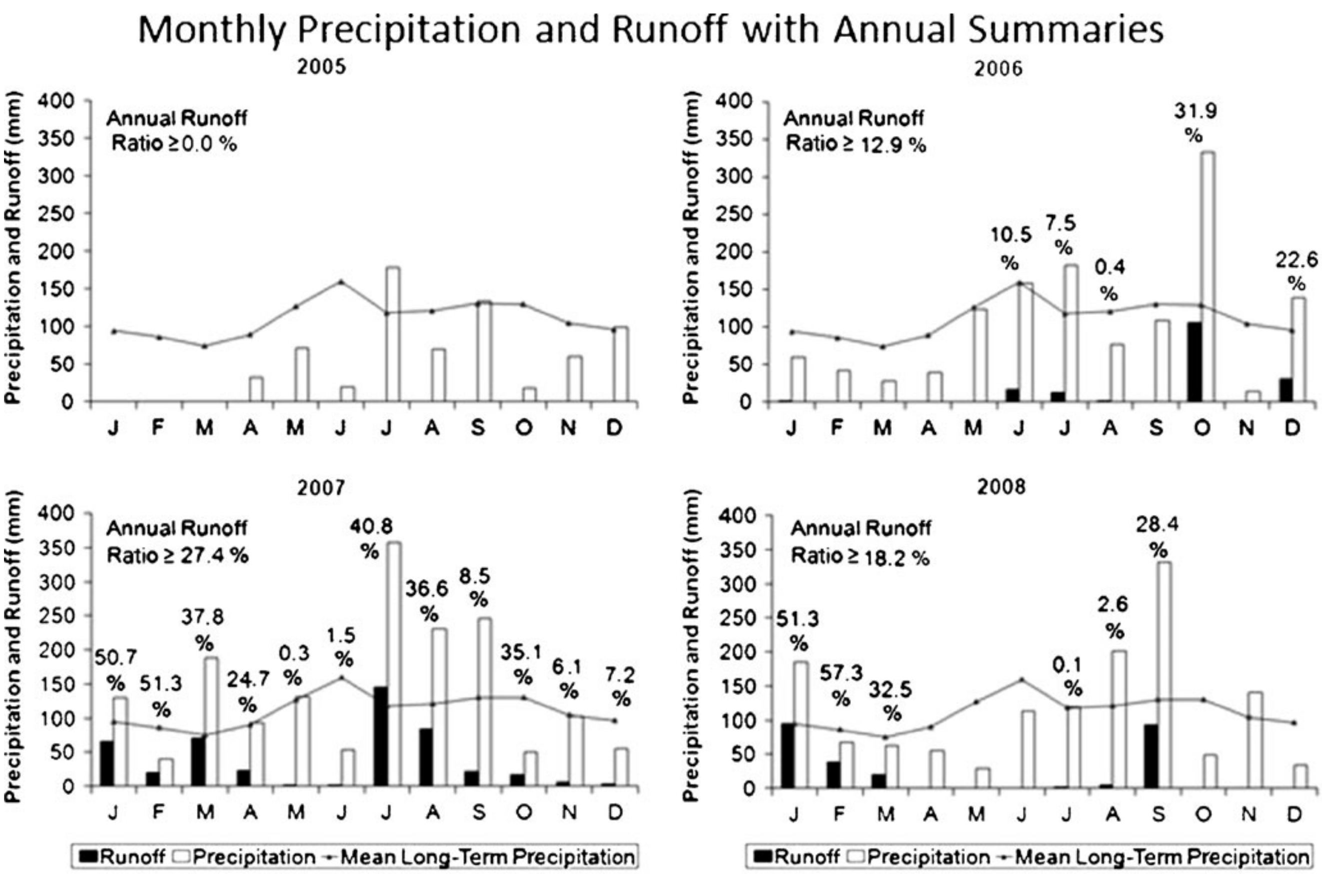

Fig. 3 Monthly precipitation and runoff for the four years of the study (2005–2008). Runoff volume is expressed as a uniform depth over the watershed (mm). The percentage of rainfall discharged as runoff is shown for each month. The line represents average monthly precipitation since 1929, for comparison

clay loam over clay to about 2 m. It is listed on the Web Soil Survey with a moderately low saturated hydraulic conductivity (K_{sat}) class (0.2877 μm/s for the entire profile). The Leton typical profile is 30 cm of loam over clay loam to about 150 cm, with a listed K_{sat} of 2.6 μm/s for the entire profile. The depressional Leton soil, at least in this area, has a substantially lower K_{sat}. We have observed dry soil at less than 25-cm depth under ponded conditions

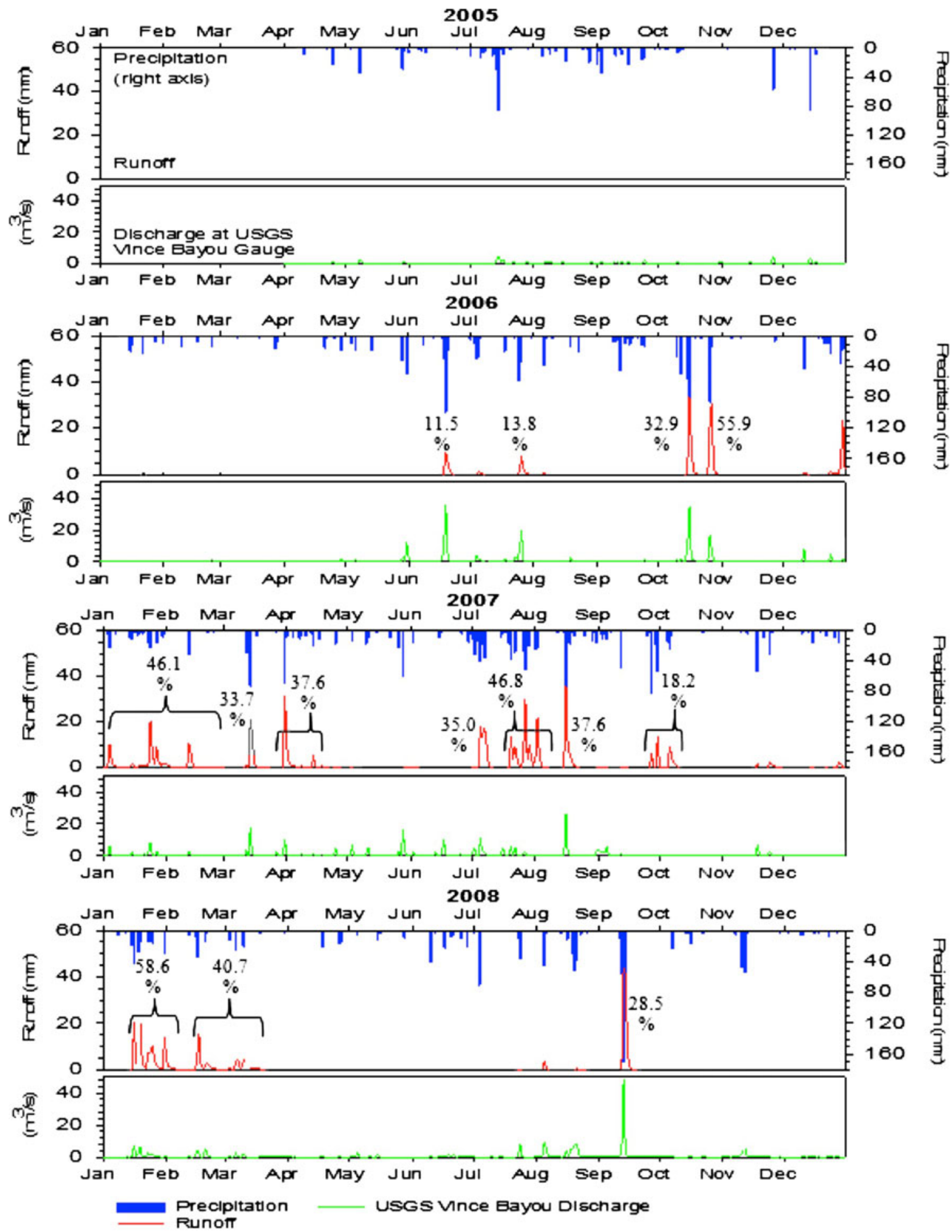

Fig. 4 Annual hydrographs (2005–2007) of daily precipitation and runoff data (axes plotted at different scales for clarity). Runoff percentages are given for major events, and the rate of runoff at the USGS gauge on Vince Bayou is shown for each year. Event-based runoff percentages were calculated from the first precipitation event following a 24-hr dry period to the beginning of the first 24-hr period with no runoff. Gaps indicate no runoff or no data

for a month or more. Saturation appears to occur from the top down, as indicated by the “Epi” formative element in the taxonomic classification of the Verland soil series.

Drainage features are quite subtle, with the watershed’s outlet stream—which becomes evident about 60 m from the center of the largest, farthest-downslope depression—only about 2 m wide and 10 cm deep. Towards the base of the study watershed, a small incised channel has developed that drains into the nearby tidal Armand Bayou.

Methods

We delineated the boundaries of the watershed during a period of saturation and runoff, using flags and a handheld GPS unit. Most of the boundary was easily discernible, but in some instances flow direction had to be used to identify its location. An elevated trail formed the southern boundary of the watershed (see Fig. 2).

We measured watershed runoff at the outlet using a 90° V-notch weir equipped with a sonar water-level recorder (Infinities USA) and rainfall was measured with a tipping-bucket rain gauge (Infinities USA). The weir was installed across the head of the incised, intermittent stream channel that runs from the watershed outlet into the Armand Bayou (an intermittent channel is one that holds water during wet periods of the year but is periodically dry—Svec et al. 2003). The water level in the weir was converted to runoff in m^3/sec by means of the Kindsvater-Shen equation (USBR 1997). The volume of water per unit of time was converted to depth of water per unit of time by dividing the volume by the area of the watershed. Readings from the water-level recorder and the rain gauge were collected at 10-min sampling intervals until January 19, 2008, and at 20-min intervals thereafter. The flow data were compared with data from the 23-km^2 watershed of the USGS-gauged Vince Bayou (USGS-08075500) (http://waterdata.usgs.gov/tx/nwis/current/?type=flow), a site near Armand Bayou that is largely urbanized (Fig. 2).

There were occasional data gaps due to equipment problems. For the precipitation record, we were able to supplement the on-site measurements with daily rainfall data from the nearest official National Climatic Data Center (http://www.ncdc.noaa.gov/oa/ncdc.html) weather station, which is about 18 km to the south of our study area (Houston NWSO, 29°28′N/95°05′W, records available November 1990–present).

Results

The 45 months during which we studied this wetland complex (Fig. 3) included years with significantly below-average (2005), near-average (2006 and 2008), and above-average (2007) rainfall. There was no wetland outflow during 2005, which was among the driest years on record for this region. When rainfall was about average or above, surface runoff ranged between 13% and 28% of watershed precipitation. The highest runoff volume occurred in 2007. Over the study period as a whole, including 2005, surface runoff from the wetland accounted for more than 17% of watershed precipitation.

Wetland runoff occurred throughout the year and was observed during 21 of the 45 months of the study, most often when monthly precipitation approached or exceeded the long-term monthly average. Occasionally, runoff occurred in months of below-average rainfall, but in most of these cases rainfall had been above average in the preceding months. During normal years, the monthly runoff threshold corresponded to around 130 mm of rainfall.

Runoff was measured during 37 days in 2006, 180 days in 2007, and 80 days in 2008. In general, runoff was highly episodic and strongly associated with individual rainfall events (Fig. 4), but there were occasional periods of extended flows, the longest being 68 days, that lasted well beyond the rainfall event. Periods of continuous runoff ranged from four days to 68 days, and averaged 17 days. For some individual events, runoff accounted for as much as 60% of watershed rainfall.

The episodic nature of the runoff is explained in part by the fact that precipitation from smaller events can be completely stored within the wetland depressions and shallow soil horizons, and in part by the fact that a significant portion of annual precipitation comes by way of large storms. From 2006 to 2008, storms that produced major runoff events accounted for between 37% and 62% of annual rainfall.

Interestingly, runoff from the study site was synchronous with that measured from the nearby Vince Bayou USGS location (Fig. 4). Baseflow in Vince Bayou is minuscule, with median flow rates ranging from 0.05 to 0.08 $m^3\ s^{-1}$ (0.2–0.3 mm/day); however, during major events, the rate of flow through the bayou was as high as 48.14 $m^3\ s^{-1}$ (180 mm/day). Runoff from Vince Bayou is largely episodic, exhibiting strong similarities with the hydrographs of runoff from the study watershed near Armand Bayou. The urbanized Vince Bayou watershed was slightly more responsive to rainfall than the study watershed, probably because of its limited water-storage capacity. Once the storage capacity of the study watershed was satisfied, its runoff response was very similar to that of Vince Bayou.

Discussion and Conclusions

Our results demonstrate that the Armand Bayou wetland complex has a strong surface-water connection with the surrounding waterways. In fact, as highlighted in the comparison with Vince Bayou, the surface connectivity of the wetland complex was not very different from that of the surrounding urban landscape. This is perhaps not a surprising result given that streams originating within the Coastal Plain typically exhibit episodic flow regimes because of the lack of baseflow, attributable to the very low permeability of the region's soils, which inhibits groundwater input.

An important question, of course, is whether our results can be generalized for depressional wetlands on the Pleistocene Texas Gulf Coastal Plain. We believe they can. As noted earlier, most of these wetlands appear to be connected by intermittently flowing channels that are vegetated with wetland plants and containing wetland soils (Jacob and Lopez 2005; Sipocz 2005); on that basis, they do not strictly meet the definition of geographic isolation. Further confirmation of surface hydrological connectivity is provided by Forbes et al. (2009), who monitored outflow for one year at six wetland locations on the Texas Gulf Coast. They reported that runoff occurred from all of the monitored locations. Coupled with these observations, our findings provide strong evidence that shallow wetland depressions on the Pleistocene Texas Coastal Plain are not closed systems. Whenever their storage capacity is exceeded, they discharge excess water downslope, and their runoff is significant.

The issue of hydrological connectivity is not simply an academic one. Under current interpretations, whether or not a wetland is regulated under the CWA depends largely on its connection to traditionally navigable waters of the U.S. (Leibowitz et al. 2008). Wetlands have well-documented functions, such as serving as pollutant sinks, that can play a critical role in maintaining the water quality of receiving streams (Mitsch and Gosselink 2000). A critical question in terms of wetland jurisdiction and regulation under the CWA is the nature of the connection to receiving water bodies: is it significant enough to affect "the chemical, physical, and biological integrity of the nation's waters"—the maintenance of which is the purpose of the CWA (33 U.S.C. §§ 1251–1387).

The idea of a "significant nexus" has emerged as perhaps the most important legal concept for wetlands jurisdiction (Murphy 2007) and is a common thread in several recent Supreme Court rulings on wetlands, especially in Rapanos v. United States (2006), their most recent case on this issue. In a complex and unusual 4–1–4 split ruling, the actual documentation of the significant nexus from seasonally saturated wetlands to "waters more readily understood as navigable" emerged as a deciding factor in assigning jurisdiction where the hydrologic connection is "not relatively permanent" (Leibowitz et al. 2008). Justice Kennedy, the "1" in the 4–1–4 ruling, specified that the significant nexus would have to be more than "speculative or insubstantial," and thus set the stage for scientific documentation of the "flow characteristics and functions" of headwater wetlands adjacent to non-navigable tributaries (USEPA 2008), precisely the wetland type examined in this study.

In summary, our detailed evaluation of runoff over nearly four years reveals that surface outflow, although episodic, is a common event in wetlands that have been considered to be geographically isolated, and accounts for a substantial percentage of the water budget. In other words, hydrological connectivity is clearly present and is not limited to an occasional event or an extraordinarily wet period. The findings of our study are important because they fundamentally contradict the notion that wetland depressions on the Pleistocene Texas Gulf Coastal Plain are hydrologically isolated from adjacent waterways (Tiner et al. 2002; Tiner 2003b).

This study provides the kind of documentation called for by Justice Kennedy in the Rapanos decision (see above). It demonstrates a "substantial" nexus between headwater depressional wetlands on the Pleistocene Texas Coastal Plain and navigable waters of the U.S.—a nexus that is not speculative but is the result of scientific observation. While further study is warranted and needed, this study and that of Forbes et al. (2009) suggest that unless demonstrated otherwise, depressional headwater wetlands—at least on the Upper Texas Gulf Coastal Plain as a class—should be considered as hydrologically connected to navigable waters of the U.S. and thus may play a critical role in the maintenance of the aquatic and biological integrity of U.S. waters in this region.

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Bay Oaks Country Club
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Wetlands (2012) 32:705–715
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ARTICLE

Nutrient Transformation and Retention by Coastal Prairie Wetlands, Upper Gulf Coast, Texas

Margaret G. Forbes · Jeffrey Back · Robert D. Doyle

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Abstract Coastal prairie wetlands (CPWs) are small, rain-fed depressions and flats that, together with their catchments, occupy approximately 40 % of the landscape around Galveston Bay, Texas, USA. Many CPWs are unregulated because they are perceived as "isolated" and a significant nexus has not been established. Results from sampling of precipitation and surface water of 12 CPWs revealed that CPWs had lower concentrations of nitrate- nitrogen (mean 18 μg L^{-1}) than precipitation (342 μg L^{-1}). A similar trend was observed for ammonia-N. Organic nutrient concentrations were several times higher in wetlands than in precipitation. Based on water budgets for six CPWs, net annual nutrient export rates indicate that CPWs are strong sinks for inorganic N and P; moderate sinks for organic N and P, and sources of dissolved organic carbon. Capture, storage, transformation, and pulsed releases of nutrients to Galveston Bay and its tributaries emphasize the role of CPWs in regulating water quality on a landscape scale. These finding demonstrate a nexus with navigable waters.

Keywords Water quality · Nutrient export · Isolated wetlands · Nexus · Cumulative wetland function · Nitrogen · Phosphorus · Carbon · Atmospheric deposition

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Introduction

Coastal prairie wetlands (CPWs) occur as a mosaic of depressions, ridges, intermound flats, and mima mounds from western Louisiana to south Texas, along the Gulf of Mexico coastal plain, USA. These wetlands once occupied close to one-third of the landscape around Galveston Bay, Texas (Moulton et al. 1997). According to Enwright et al. (2011), CPWs and their catchments occupy 40 % of the land area around Galveston Bay, Texas. CPW loss rates are high (Jacob and Lopez 2005), in part due to the perception that they are "isolated" (Sipocz 2005) despite evidence that many have regular discharge to tributaries of Galveston Bay (Clapp 2010; Wilcox et al. 2011).

There are few studies of the cumulative effects of small water bodies such as CPWs, on broad-scale ecosystem services such as hydrology (Bedford 1996) and water quality (Whigham and Jordan 2003). Yet small water bodies (<1 km^2) account for nearly half of global freshwater area (Downing et al. 2006) and appear to have disproportionately high hydrologic and nutrient processing rates (Smith et al. 2002). Wetlands with "closed" systems have been found to retain up to 90 % of inorganic nutrient inputs compared to 5 % in "open" systems (Hopkinson 1992).

CPWs are a subset of Coastal Plains ponds listed by Tiner (2003a) as geographically isolated. Geographically isolated wetlands typically have intermittent discharge to other receiving waters and they exhibit a wide range of connectivity to traditional navigable waters. Other wetlands considered geographically isolated include prairie potholes, playas, vernal pools, sinkhole wetlands, Carolina bays, interdunal and intradunal wetlands, desert springs, terminal basins, kettle-hole bogs, farm ponds, and others. These regional systems occur over a large portion of the U.S. and have functions and values similar to "connected" wetlands such as water storage, flood control, nutrient transformation and cycling, primary productivity, shoreline stabilization, wildlife habitat, and in particular, biodiversity since many have endemic species (Tiner 2003b). In the Supreme Court Decision of Rapanos v. United States, Justice Kennedy did not question the treatment ability of wetlands and their potential importance to water quality of navigable waters, but asserted that they must possess a "significant nexus" to navigable waters (U.S. Army Corp of Engineers 2008). The requisite nexus must be assessed in terms of a wetland's functions such as pollutant trapping and flood control as they relate to the integrity of other waters. Furthermore, such effects cannot be "speculative or insubstantial".

For wetlands whose primary water source is atmospheric, a potential nexus could be based on transformation and reduction of atmospheric nutrient loads, particularly nitrogen (N). Human activity has increased the amount of N cycling between land and the atmosphere, with an exponential climb in the increase of N fixation observed over the past few decades (Vitousek et al. 1997). Atmospheric deposition of N to several coastal areas was found to be a strong predictor of N fluxes from nonpoint sources; with the deposition of atmospheric ammonium to surface waters correlated with agricultural sources (Howarth 1998). Such excess N deposition increases the potential importance of numerous but small wetlands (e.g. Coastal Plain ponds) that capture and transform atmospherically-deposited pollutants. However, few studies have quantified this function in geographically isolated wetlands.

To address this, we collected baseline water quality data at 12 CPWs. To test the hypothesis that CPWs act as sinks for nitrogen and phosphorus, we combined hydrologic and water quality data to calculate nutrient retention by six CPWs. Details on CPW hydrology and construction of the six water budgets are available in Clapp (2010).

Methods

Study Area

The study was conducted at 12 sites located within a 32-quadrangle area (Fig. 1) that surrounds Galveston Bay, Texas, USA, which includes the Houston metropolitan area. The area has a human population of more than 5 million people, one quarter of the nation's petroleum refining capacity, and more than 100 chemical refineries. In the past decade, Houston had the highest frequency of federal smog standard violations of any city in the US. Galveston Bay and many of its tributaries are eutrophic (Scavia and Bricker 2006). Despite these issues, the Bay accounts for approximately one-third of the state's fishing income, with important harvests of oysters, shrimp, and blue crab (Pinckney 2006).

Freshwater wetlands in the study area are described as partially isolated extensive wet flats and depressions within the Texas-Louisiana Coastal Prairie Ecosystem (Comer et al. 2005). Drainage in the low relief (~0.02 % slope) landscape is toward Galveston Bay and its tributaries. Most CPWs were historically dominated by grasses, but some have developed scrub/shrub or forested vegetation from lack of fire and other factors such as woody invasion by *Sapium sebiferum* (L.) Roxb, commonly known as Chinese tallow (Grace et al. 2005). The dominant soil orders are Vertisols and Alfisols that developed over Pleistocene deposits along the Gulf Coast. Groundwater exchange is generally limited in these impervious, episaturated soils (Miller and Bragg 2007; Wes Miller, personal communication, August, 2011). The region has a sub-tropical climate with soil temperatures that indicate a year round growing season (Miller and Bragg 2007). Wetlands are seasonally inundated with intermittent outflows and a water balance driven largely by precipitation and evapotranspiration.

Study Design

The 12 sites were selected to encompass a variety of vegetation, land uses, sizes, and location relative to the floodplain (Fig. 2, Table 1). Most sites were connected to nearby (~ 1 km) navigable waters by channels or ditches. Water sampling at six initial sites (CR, WD, KS, TH, SW and LC) occurred spring 2008 – winter 2010. Six additional sites were selected and sampled spring 2009 – winter 2010. Four of those sites (DW, SE, UH and LG) were randomly selected from a pool of approximately 76 CPWs outside the 100-year floodplain whose owners could be contacted. Most sampling occurred September through April because CPWs are typically dry in summer months. Hurricane Ike storm surge impacted SW and LC and these data were omitted.

Nutrient retention was based on the difference in aquatic nutrient concentrations between incoming precipitation and surface water in the wetlands. This simple black box approach ignores internal cycling of nutrients and gaseous exchanges such as denitrification. Precipitation (PPT) was collected at seven of the sites (CR, KS, LG, DW, KIL, SW and LC) in three barrels lined with plastic bags. Method blanks were used to assure that the bags did not contaminate the samples. Collections included a small amount of dry deposition (e.g. dust, insects). Typically, wetland surface water was sampled in conjunction with PPT collection, and again 7–10 days later, although other surface water sampling also occurred outside of PPT events. Surface waters were collected from multiple stations throughout the wetlands, depending on the extent of inundation. Temperature, specific conductivity, pH, and dissolved

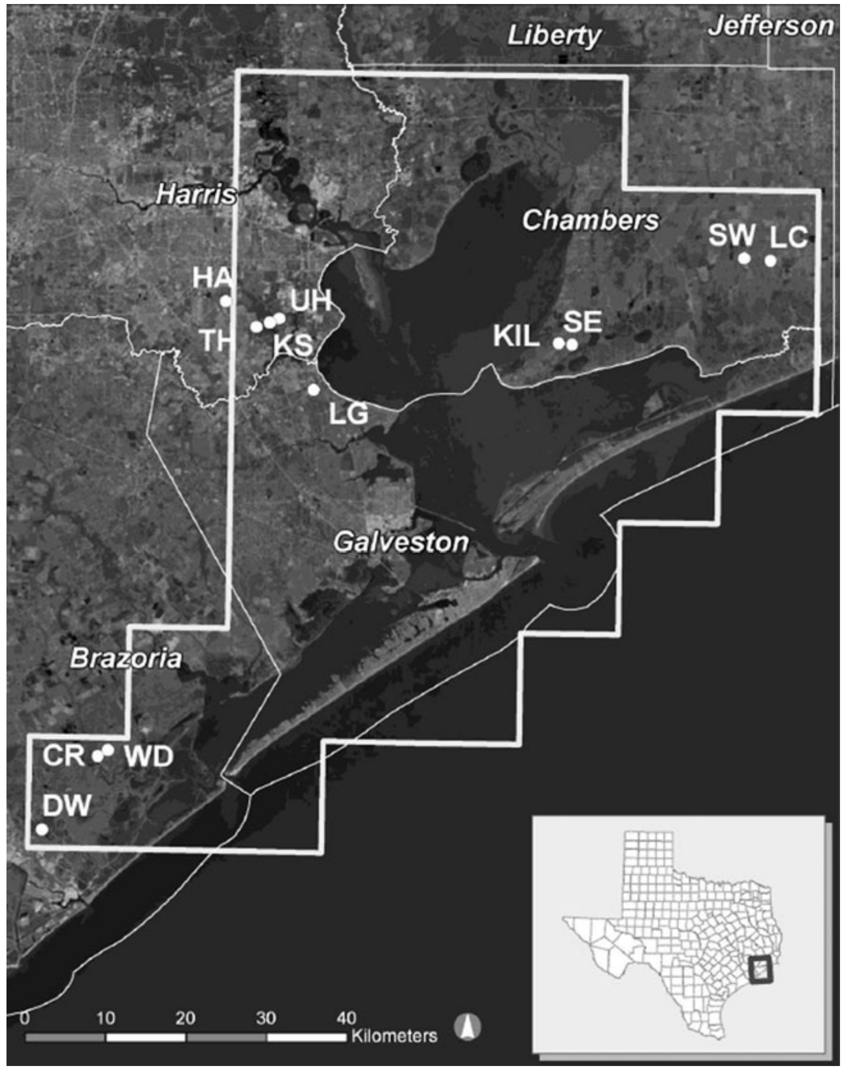

Fig. 1 Study site boundary of 32 quadrangles, county boundaries, and study site locations

oxygen were determined in situ with an YSI 600 XLM® multiparameter datasonde. Surface water grab samples were collected, placed on ice and transported immediately to the laboratory. Suspended solids were determined on 0.7 micron GFF filters dried at 103–105 °C. Filtered and unfiltered aliquots were used to determine total and dissolved nutrients with a Lachat Quickchem 8500 Flow Injection Autoanalyzer using standard colorimetric techniques (nitrate+nitrate: EPA 353.2, ammonia: EPA 350.1, phosphate: EPA 365.1). Total N and P were run on unfiltered samples digested using persulfate and subsequently analyzed using EPA methods 353.2 and 365.1 respectively. Organic N and P were defined as the difference between total and inorganic N and P. Detection limits were determined for each analytical run and averaged 1.24, 7.44, 1.67, 3.67 and 1.95 μg L^{-1} for NO_3, NH_4, SRP, TN and TP respectively. Results that were below the minimum detection limit (MDL) were reported as the MDL for that run. DOC was determined as non-purgeable organic carbon on filtered, acidified, sparged samples with a Shimadzu TOC-V_{CSN} analyzer with combustion at 680°C.

Nutrient retention values were based on differences between concentrations in PPT and concentrations in wetland surface water. The nutrient load was calculated as the product of the local volume-weighted PPT concentration (mg m^{-3}), the total PPT that fell at the site (m), and the catchment-wetland area (m^2). Nutrient export was calculated as the product of total discharge from each wetland (m^3) and the mean nutrient concentration in that wetland (kg m^{-3}). Areal annual values (kg km^{-2} y^{-1}) were obtained by dividing export by the catchment area (km^2) and the time period evaluated (y).

Statistical Analysis

We evaluated differences in nutrient concentrations among sites and PPT with two-way analysis of variance (ANOVA) using SPSS® version 18 software (IBM®). The two factors were date and site (with interaction), with PPT treated as a site. Statistical outliers were identified with Dixon's test (α=0.05)

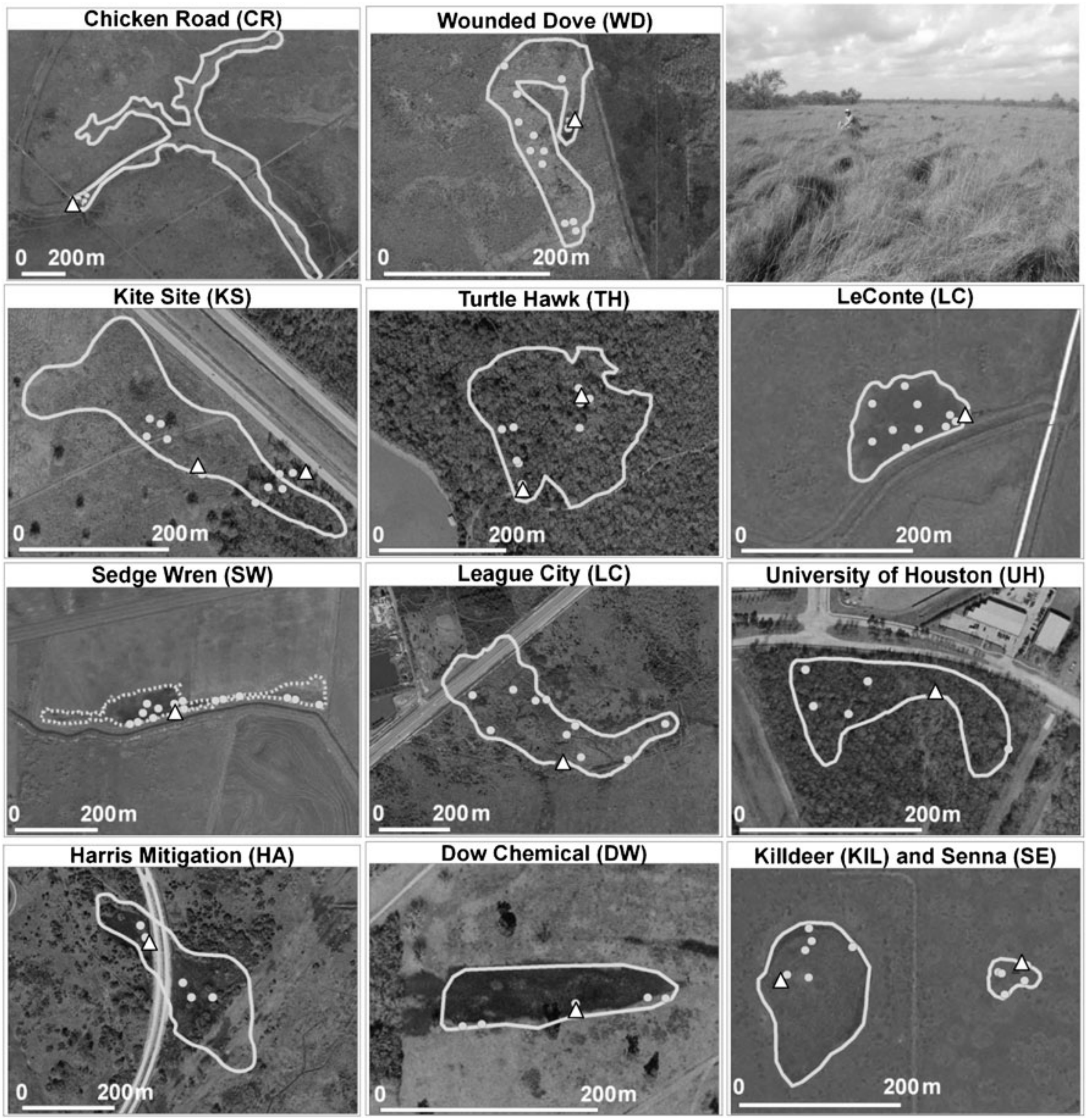

Fig. 2 Aerial photographs of 12 CPW sites and ground photograph of WD. Solid lines are NWI boundaries, broken line is estimate of wetted perimeter (SW not included in NWI). Sample locations are solid circles, water level recorders are triangles. Note different scales used for each wetland

and ProUCL Version 4.0 software (USEPA) and data with non-Gaussian distributions were normalized by log transformation prior to statistical analyses. Post hoc differences were determined with Dunnets using PPT as the control (α=0.05). A second post hoc Tukey analysis (α=0.05) was performed on the 12 CPWs (i.e. without PPT) to identify differences among wetlands, without Bonferoni correction.

Results

Twenty PPT events were sampled, representing a total of approximately 90 cm (average annual rainfall in the area is 110 cm). Solids, dissolved oxygen, pH, and conductivities in PPT were distinct from those in wetland surface water (Table 2). PPT nutrients varied considerably among the three locations, most constituents were an order of magnitude higher in the eastern Chambers County sites than at Brazoria and Harris County sites located west of Galveston Bay.

The largest portion of variability among concentrations was attributable to site, followed by date (two-way ANOVAs). Although date was a significant factor, there were no clear seasonal trends in water quality. Interactions between site and date was a significant but minor contribution to total variability. Variability among different sampling

Table 1 Summary characteristics of wetland sites. Catchment size includes wetland area. Land use categories: WR=wildlife refuge, NA=natural area, GP=grazed pasture

Site	NWI code	Longitude (W)	Latitude (N)	Wetland size (ha)	Catch: Wet ratio	Within 100-yr floodplain?	Land use/adjacent land use
CR	PEM1C	95.28740	29.10366	10.4	4.9	Yes	WR/WR
SW	PEMf	94.46955	29.67314	2.4	8.6	Yes	WR/Agriculture
WD	PEM1C	95.27451	29.11055	1.5	1.9	Yes	WR/WR
TH	PFO1A	95.07763	29.59315	4.8	1.3	No	NA/NA
KS	PFO1A	95.06553	29.59794	3.4	35.0	Partially	NA/Commercial
LC	PSSf	94.43611	29.67100	1.0	12.1	No	WR/Agriculture
LG	PEM1A	95.01972	29.51859	9.6	7.1	No	NA/Residential
KIL	PEM1F	94.70628	29.57501	1.6	1.6	No	GP/GP
DW	PEM1C	95.35685	29.02015	1.0	3.9	No	GP/Industrial
HA	PEM1C	95.13431	29.61630	3.1	3.7	No	NA/Residential
UH	PFO1A	95.09415	29.58777	1.6	33.3	No	NA/Residential
SE	PEM1A	94.70388	29.57519	0.2	7.0	No	GP/GP

locations within a CPW on a given date was low, as suggested by low residual errors for all parameters. While most CPW nutrient concentrations were significantly different than those in PPT, there were few statistically significant differences among the 12 wetlands (Fig. 3, Tukey, α=0.05).

Inorganic-N concentrations in PPT were an order of magnitude higher than in wetland surface water (Table 3). Inorganic-N in PPT accounted for approximately 50 % of the total nitrogen in PPT, while it comprises only 3 % of total N in wetland surface water. Ammonia-N in CPWs was over six times lower in CPW surface waters than in PPT, while wetland nitrate-N was even lower. The ability of these wetlands to eliminate nitrate-N was noted when samples collected at KS on 7 March 2009 revealed extremely high NO_3-N concentrations (6,244 μg L^{-1}, see "X" symbols, Fig. 3b), due to recent herbicide spraying with Picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid). Eight days later, KS surface waters had a mean NO_3-N of 2.2 μg L^{-1}. Subsequent samples from KS also exhibited low nitrate levels.

Organic-N (as well as inorganic-N) in PPT varied strongly by location, with values from locations east of Galveston Bay being much higher than those to the west. The range of organic-N concentrations was also higher in PPT due to occasionally lower organic-N values in PPT (Fig. 3c). Organic-N in wetland surface water ranged from slightly

Table 2 Water quality summary for PPT and twelve coastal prairie wetlands. The initial 6 wetlands are listed first. Log-transformed SD (in parentheses) for total suspended solids (TSS), arithmetic SD for other parameters. Grand means and median from individual site means (n=12)

Site	Number of sampling events	n	Depth cm	Temp °C	Specific Conductivity mS cm^{-1}	DO %	pH	TSS mg L^{-1}
PPT	20	30	–	20±5.7	0.10±0.09	104±9.4	5.7±1.0	8.8 (8.2)
CR	11	58	22±13	19±4.6	2.0±2.4	58±37	6.5±0.3	17 (3.2)
WD	9	39	13±8.7	18±6.2	0.3±0.1	62±46	6.8±0.4	62 (3.4)
TH	9	29	9±6.2	22±6.2	0.1±0.05	69±29	6.4±0.5	19 (2.9)
KS	10	31	13±7.6	22±6.3	0.6±0.7	73±19	6.2±0.6	28 (2.5)
LC	4	13	12±4.6	18±4.7	1.3±0.7	119±35	7.2±0.5	26 (2.6)
SW	7	42	17±13	19±4.8	3.1±3.4	66±36	6.5±1.0	15 (2.4)
LG	5	23	15±6.7	20±5.6	0.14±0.06	64±26	6.2±0.4	21 (3.0)
KIL	5	18	26±7.6	19±5.0	14.8±1.1	125±21	8.4±0.4	23 (2.1)
DW	4	15	19±8.7	21±9.1	0.1±0.04	72±40	6.3± 0.3	24 (2.8)
HA	2	7	15±8.0	14± 1.9	0.1±0.05	77± 25	6.3± 0.3	21 (2.0)
UH	2	7	4±1.8	15±2.1	0.9±0.06	52±9.7	6.7±0.6	37 (2.8)
SE	2	5	3.5±1.3	14±6.3	0.3±0.2	107±18	6.7±1.4	22 (3.5)
Grand Mean (± SD) CPWs		12	14±1.9	19±0.8	2.0±1.2	77±6.2	6.7±0.2	27±2.2
Median of CPWs		12	14	19	0.4	70.5	6.5	22.5

Table 3 Summary of means and (SD) of nutrient concentrations in twelve coastal prairie wetlands. PPT means for three locations are provided in addition to mean for all events (all volume-weighted). The grand mean, standard error, and median of site means (n=12)

Site	County	N	SRP μg L^{-1}	NH_4-N μg L^{-1}	NO_3-N μg L^{-1}	org-N μg L^{-1}	org-P μg L^{-1}	DOC mg L^{-1}
PPT	All locations	20	34	258	354	500	58	2.5
PPT	Brazoria	5	12	129	116	215	21	0.8
PPT	Harris	8	6.6	275	132	227	31	1.0
PPT	Anahuac	7	260	216	1024	1223	141	7.2
CR	Brazoria	59	14 (2.4)	42 (3.6)	5.4 (2.7)	1659 (1.5)	113 (2.1)	26 (1.3)
WD	Brazoria	41	23 (2.2)	68 (2.8)	3.6 (1.7)	1439 (1.4)	136 (2.0)	22 (1.4)
TH	Harris	32	19 (1.8)	74 (2.2)	18 (5.7)	1741 (1.9)	105 (2.1)	26 (1.7)
KS	Harris	31	18 (1.7)	47 (2.7)	[a]9.6 (15)	2076 (2.2)	125 (2.3)	25 (1.7)
SW	Anahuac	42	16 (1.2)	38 (2.9)	4.2 (1.5)	1630 (1.3)	205 (1.9)	16 (1.2)
LC	Anahuac	14	24 (2.5)	34 (4.5)	6.7 (1.9)	2633 (1.3)	253 (1.9)	34 (1.2)
LG	Harris	23	15 (1.6)	37 (1.8)	2.0 (3.0)	2039 (1.4)	66 (1.9)	28 (1.3)
KIL	Anahuac	18	17 (1.7)	19 (3.3)	3.7 (1.4)	2876 (1.1)	113 (1.6)	36 (1.2)
DW	Brazoria	16	111 (3.5)	33 (2.9)	2.8 (1.6)	1847 (1.4)	479 (1.9)	16 (1.4)
HA	Harris	8	12 (1.5)	36 (2.4)	4.9 (1.3)	1765 (1.4)	75 (2.3)	19 (1.2)
UH	Harris	8	16 (2.4)	26 (1.6)	153 (12)	2511 (1.8)	116 (1.5)	39 (1.7)
SE	Anahuac	6	8.8 (1.5)	15 (2.9)	4.4 (1.4)	3572 (1.5)	255 (2.4)	34 (1.3)
Grand mean (± SD) CPWs		12	24±8	39±5.0	18±12	2149±182	170±34	27±2.0
Median CPWs		12	16.5	35	5.2	1943	121	26

Note: a. includes KS samples after herbicide spraying. KS means without herbicide samples=4.8 μg/L

higher to approximately four times that in PPT. Filtered CPW waters were visibly stained with humics, suggesting that soluble plant-derived organics dominate these heavily vegetated wetlands.

Nitrogen input, export, and net retention at six of the sites (Table 4) indicate that all six wetlands were strong sinks for inorganic nitrogen, retaining 98 % of the NH_3-N and 99.9 % of the NO_3-N load in PPT. These rates reflect both lower DIN concentrations in wetland surface water and high water storage capacities. Four of the six CPWs were also sinks for organic-N, despite the fact that organic-N concentrations were substantially higher in the wetlands than in PPT. One site, TH, was a net source of organic-N, while another site, LC, was neither a source nor sink. The LC wetland had high water discharge rates relative to the other sites, in part because during larger runoff events, an upgradient wetland contributed flow to the ditch where our outlet weir was located, resulting in an overestimation of discharge. CPWs retained an annual average of 56.7 % of the organic-N deposited in PPT. Soluble reactive phosphate (SRP) spanned three orders of magnitude in PPT samples (Fig. 3d) and the mean concentration in rainfall was not significantly different than CPW surface water in nine of the twelve CPW's. One wetland, DW, had a higher mean SRP and two sites, HA and SE, had lower SRP concentrations than PPT.

Mean organic-P was 2.9 times higher in wetland surface water than in PPT; and all of the sites were significantly higher than PPT (α=0.05; Fig. 3e). Despite these higher concentrations, most of the wetlands acted as strong sinks for SRP (Table 5, mean retention 92 %) with LC acting as neither a source or sink. Annual export rates of SRP ranged from 0.5 to 13.3 kg km^{-2}y^{-1}, while organic-P export ranged from 3.6 to 140 kg km^{-2}y^{-1}. Variability in organic-P (as with organic-N) was driven primarily by hydrology rather than nutrient concentrations.

As expected, dissolved organic carbon (DOC) was substantially higher in wetland surface water than in PPT. All CPWs had high DOC concentrations and there were no differences among sites (Fig. 3f). Four of the sites were net sources of DOC, while two were weak sinks. Areal annual export of DOC ranged from 709 to 19,880 kg km^{-2}y^{-1}.

The mean molar ratios of PPT inorganic-N and -P (TIN: SRP) was 74.5 compared to a 5.31 in the 12 CPW's. Mean TN:TP in PPT was 47.3 which was also higher than that in CPWs (25.2). Relative to the Redfield Ratio (molar N:P~ 16), PPT is nitrogen rich and CPWs are nitrogen poor with respect to inorganic–N but not organic-N. The inorganic portion of N in PPT averaged 51 %, and in CPWs was only 3 %. Inorganic phosphorus in PPT averaged 28 % of total P, while in CPWs the inorganic component was only 12 %. Organic C:N ratio of PPT was 5.8, while wetland surface water C:N was 14.6.

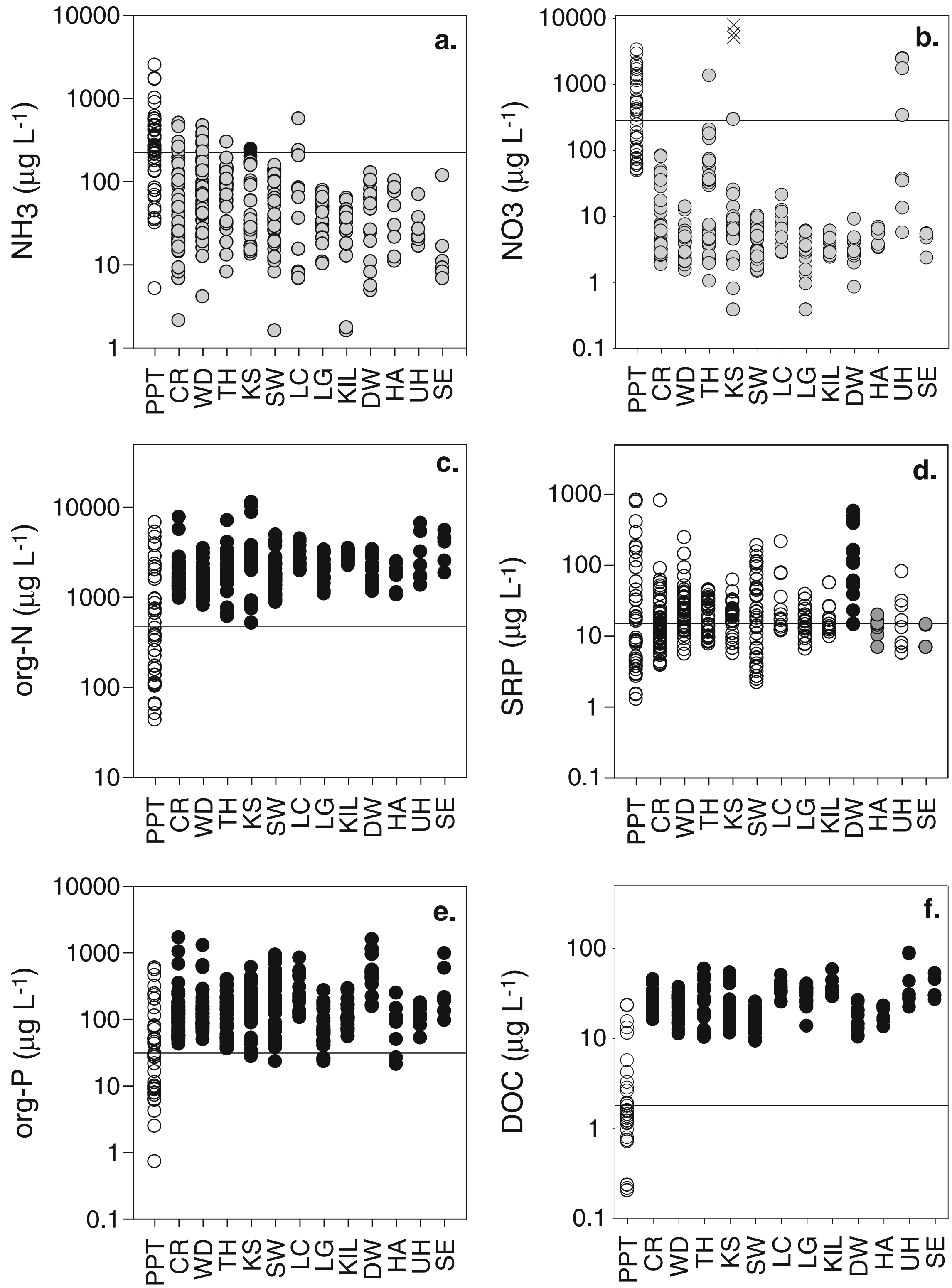

Fig. 3 Nutrient concentrations in PPT and surface waters of 12 CPWs. Nutrients include **a**) NH_4-N, **b**) NO_3-N, **c**) organic nitrogen, **d**) SRP, **e**) organic phosphorus, and **f**) dissolved organic carbon. The solid horizontal lines are the PPT geometric means. Wetlands with open symbols had means that were not significantly different than PPT, those with black symbols were higher, and those with gray symbols were lower (α=0.05). X symbols in b indicate samples collected after herbicide spraying

Table 4 Annualized areal nitrogen loads (N-In), export (N-Out), and percent retained at 6 coastal prairie wetlands. Geometric means and SD are given for percent retained

Site	N-In (kg N$km^{-2}y^{-1}$)				N-Out (kg N$km^{-2}y^{-1}$)				Percent Retained (%)			
	NH_3-N	NO_3-N	org-N	TN	NH_3-N	NO_3-N	org-N	TN	NH_3-N	NO_3-N	org-N	TN
CR	119	107	197	402	2.8	0.4	112	115	97.6	99.7	43.4	71.5
WD	119	107	197	402	3.4	0.2	73	76	97.1	99.8	63.1	81.0
TH	393	189	324	897	21.2	5.2	535	561	94.6	97.3	-65.0	37.4
KS	393	189	324	897	1.3	0.3	65	66	99.7	99.9	80.0	92.6
LC	267	1263	1508	3038	18.8	5.9	1475	1500	93.0	99.5	2.0	50.6
SW	267	1263	1508	3038	3.4	0.4	147	151	98.7	100	90.3	95.0
Geometric Mean	232	294	458	1031	5.1	0.8	198	205	97.8	99.7	56.7	80.1
SD	1.73	3.18	2.58	2.49	3.1	4.7	3.5	3.4	1.0	0.4	23.8	9.5

Discussion

Atmospheric inorganic-N deposition in this study were similar to those from the nearby National Atmospheric Deposition Program (NADP, Station TX10), after adjusting for dry deposition (40 % of total deposition nationwide, Meyers et al. 2001). Our annual TN load from PPT (1,031 kg N $km^{-2}y^{-1}$) was higher than Byun's (2008) model for Galveston Bay's lower watershed (811 kg N $km^{-2}y^{-1}$); but within the range of that identified by Meyers et al. (2001) of 891 and 1,264 kg N $km^{-2}y^{-1}$ for the Bay and nearby Terrebonne Bay, respectively. Atmospheric organic-N consists of gas, particles and dissolved phases. Globally, organic-N accounts for about 30 % of total N that is atmospherically deposited, although spatial-temporal variability is large (Cape et al. 2011). The components of atmospheric organic-N are chemically complex, ranging from simple small molecules to complex biological polymers (Cape et al. 2011). In wetlands, the largest component of the nitrogen stock is in the sediments, followed by vegetation (Bowden 1987). Thus the organic-N exported from CPWs is likely comprised of autochthonous, humic material with fundamentally different characteristics than organic-N in PPT. In fact, given plant uptake rates for various wetland types of 500 to 35,000 kg N $km^{-2}y^{-1}$ (Bowden 1987), plant uptake alone could accommodate deposited N. Moreover, the assimilative capacity of CPWs likely exceeds the atmospheric loads they currently receive.

Water exported from CPWs had lower inorganic-N and higher organic-N concentrations than values reported for most streams. Median NO_3-N in CPWs was 5 µg L^{-1}, compared to a range of 130 to 200 µg L^{-1} for streams within undeveloped basins in the Southeast (Clark et al. 2000). Median TN in CPWs (1.96 mg L^{-1}) was 4 times the 75th percentile in southeastern streams (>0.5 mg L^{-1}) and 7.5 times the national median of 0.26 mg L^{-1}. The Clark et al. (2000) national maximum TN concentrations (2.6 mg L^{-1}) and export (840 kg $km^{-2}y^{-1}$) occurred in drainage from a forested swamp. While this study's mean TN concentration was similar at 2.2 mg L^{-1}, smaller CPW discharge volumes resulted in lower TN export (205 kg $km^{-2}y^{-1}$). Annual areal exports of nitrate ranged from 0.2 to 5.9 kg NO_3-N $km^{-2}y^{-1}$ which is much lower than the 11 to 87 kg NO_3-N $km^{-2}y^{-1}$ reported for streams in southeastern basins (Clark et al. 2000). Thus CPWs may function as an important control

Table 5 Annualized areal SRP, organic-P, TP and DOC loads (In), export (Out), and percent retained at 6 coastal prairie wetlands

Site	In (kg $km^{-2}y^{-1}$)				Out (kg $km^{-2}y^{-1}$)				Percent Retained (%)			
	SRP	Org-P	TP	DOC	SRP	Org-P	TP	DOC	SRP	Org-P	TP	DOC
CR	11	20	43	702	0.9	7.7	8.6	1690	91.4	60.9	71.9	-140
WD	11	20	43	702	1.1	6.9	8.1	1090	89.5	64.6	73.5	-55
TH	9	44	66	1392	5.4	30.9	36.4	7440	42.2	29.6	31.4	-435
KS	9	44	66	1392	0.5	3.8	4.3	710	94.6	91.3	91.9	49
LC	137	174	57	8840	13.3	173	186	19880	90.3	0.8	39	-125
SW	137	174	57	8840	1.2	18.0	19.2	1600	99.1	89.7	93.7	82
Geometric Mean	24	53	79	2052	1.9	16.4	18.4	2600	92.1	69.1	76.8	-26.7
SD	3.8	2.7	2.9	3.2	3.4	3.9	3.9	3.6	21	35	26	185

on NO_3-N availability in Galveston Bay, where high inorganic N concentrations have been linked to phytoplankton blooms (Pinckney 2006).

Concentrations of SRP were roughly similar in most CPWs and PPT, with the exception of Chambers County PPT. Land use in Chambers County is primarily agricultural, with frequently exposed soils that increase particulate matter in PPT. Thus dust-soil particles may have contributed to higher SRP (and N) in PPT. In addition, prevailing winds are from the south and west, potentially depositing higher loads of N and P on the eastern sites. Net SRP retention was 89 %, indicating that CPWs are strong sinks for inorganic-P. This is consistent with 90 % retention of inorganic nutrients found in soil, detritus and biomass within a closed wetland (i.e. one that has weak exchange of materials) in the southeastern U.S. (Hopkinson 1992). The role that CPWs play in regional P retention has not been evaluated. However, in other catchments with stagnant water bodies (lentic systems including wetlands, lakes, etc.), SRP export was lower and TP export less variable than in catchments without stagnant water bodies (Alvarez-Cobelas et al. 2009). In addition, the inverse of riparian wetland coverage has been found to be a strong predictor of P loading to Lake Champlain (Weller et al. 1995).

Dissolved organic carbon is one of the most important exports from wetland systems (Schiff et al. 1998). Terrestrial and marsh-derived DOM (as opposed to plankton-derived DOM) has been found to be significant in regulating DOM seasonal cycles within estuarine systems (Mannino and Harvey 2004; Flynn 2008). Furthermore, the quality of DOC exported from wetlands may be important to the global carbon cycle, as it is typically high in humic substances that decompose relatively slowly (Qualls and Richardson 2003) with properties that inhibit cyanobacteria blooms (Imai et al. 1999). Spatially explicit models of organic matter have found that wetlands exported 3.5 times more DOC than non-wetland landscapes; and that globally, wetlands were the source of 23 % of all DOC exported to coastal waters (Harrison et al. 2005). As with N and P, DOC export has been found to be well correlated to watershed wetland area (Agren et al. 2008; Wilson and Xenopoulos 2008), with organic carbon export from five watersheds with considerable swamp drainage being several fold higher than export rates from upland watersheds (Mulholland and Kuenzler 1979).

Concentrations of DOC in CPW surface waters (mean 27, range 13–39 mg L^{-1}) were comparable to those in other wetland studies (Newman and Schalles 1990; Opsahl 2005). The annual total organic carbon (TOC) load from the Trinity River, the main water source to Galveston Bay, was estimated by Warnken and Santschi (2004) to be 11.2×10^{10} g C. Based on our export rates and the CPW catchment coverage of 1,221 km^2 (Enwright et al. 2011), annual DOC export from CPWs range from 8.7×10^8 to 2.4×10^{10} g C. Thus, CPWs provide a substantial portion of the annual organic carbon load to the Galveston Bay system.

As linkages increase between non-point sources such as fertilized fields and high atmospheric N deposition (Howarth 1998; Howarth et al. 2002), the role of small water bodies in ameliorating N pollution will increase (Fig. 4). In other regions, researchers found that watersheds with more land area in wetlands have reduced instream nitrate concentrations (Demissie and Khan 1993; Pellerin et al. 2004; Hayakawa et al. 2006). Using N loading and land use estimates for the lower Galveston Bay watershed (Newell et al. 1992), we analyzed changes in N export that would result if CPWs and their catchments were converted to equal parts urban and residential land uses. We presumed that the land areas comprising CPW catchments were also converted from 80 % open land/pasture and 20 % agricultural land. Without CPW processing, N export increased by a factor of 1.9, from 6.6×10^6 to 12.4×10^6 kg N y^{-1}. These estimates

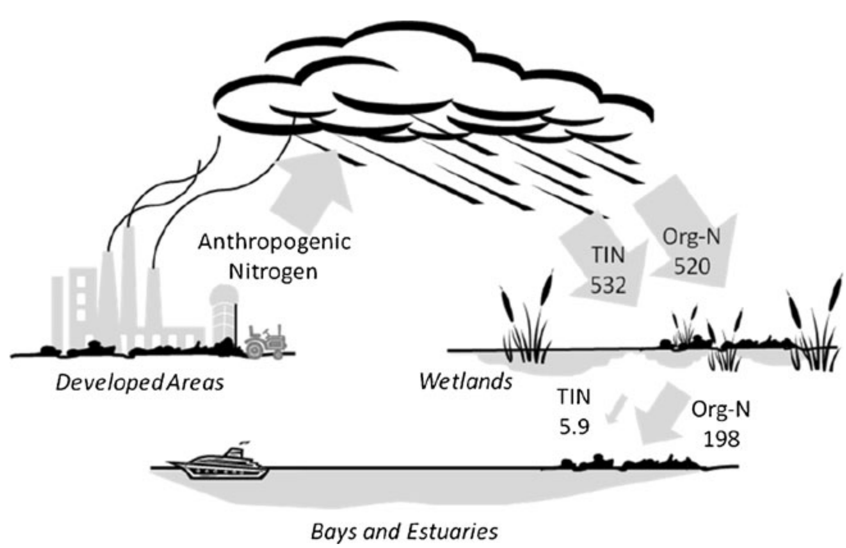

Fig. 4 Role of coastal prairie wetlands in atmospheric nitrogen cycle, Upper Gulf coast, Texas, showing anthropogenic nitrogen sources, deposition in coastal prairie wetlands, and discharge to near coast receiving waters. Values are in kg N$km^{-2}y^{-1}$. TIN=total inorganic nitrogen, Org-N=organic nitrogen

highlight the importance of the wetland's catchment area; as even in developments where small wetlands are conserved, runoff is often re-routed around the wetland. This not only compromises the wetland's hydrology, but also deprives society of many of the functions (e.g. water storage, pollutant removal, carbon export) provided by the wetland.

Significant nexus can derive from "functions that may significantly affect the physical, chemical, or biological integrity of downstream traditional navigable waters include nutrient cycling and removal and transferring nutrients and organic carbon vital to support downstream food webs" (U.S. Army Corp of Engineers 2011). Our analyses indicate that CPW's collect and store approximately 76 % of PPT falling within their catchments (Clapp 2010), and retain 98 % of inorganic-N and 92 % of inorganic-P. In addition, they provide a substantial portion of total annual DOC to Galveston Bay. The impacts on regional water quality from the continued loss of CPWs would be expected to have measurable and significant impacts on regional water resources.

These estimates include errors associated with measured variables such as precipitation and discharge volumes as well as potential omissions such as groundwater exchange and dry deposition. For example, total deposition was underestimated because dry deposition was only collected for a short time prior to rain events. Groundwater exchanges were presumed to be negligible, but this may not be true for all sites, particularly those located in remnant channels.

Nutrient concentrations used to calculate wetland exports were based on mean concentrations from all dates; yet concentrations may have been more dilute during discharge events. This study calculated areal rates of retention for CPWs and their catchment areas, thus the nutrients sequestered within the catchment were not separated from those sequestered within the wetland. On the other hand, boundaries between catchment and CPWs are dynamic, the flat topography and small catchment areas resulting in wetted areas that expand and contract.

Conclusions

Coastal prairie wetlands are important components of the Upper Gulf Coast landscape, that, together with their catchments, capture approximately 40 % of the PPT falling on the land area around Galveston Bay. They regularly discharge water, energy, and material, primarily organic nutrients, to nearby waters of the U.S. Based on the six CPWs evaluated, they act as very strong sinks for inorganic-N (98 %) and inorganic-P (92 %). Their organic N and P concentrations are higher than those in PPT, but due to low water discharge rates, they are also sinks for organic N and P. Estimates indicate that CPWs could provide as much as half of the annual organic carbon load to the Galveston Bay system. Water discharges from CPWs have lower NO_3-N and higher organic-N concentrations than values reported for most streams in undisturbed watersheds nationwide. The conversion of CPWs and their catchments to urban and residential land uses would nearly double the total N load exported by Galveston Bay's lower watershed. Capture, storage, transformation, and pulsed releases of organic nutrients to Galveston Bay and its tributaries emphasize the role of CPWs in regulating water quality on a landscape scale; these finding demonstrate a nexus with navigable waters.

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Weller CM, Watzin MC, Wang D (1995) Role of wetlands in reducing phosphorus loading to surface water in eight watersheds in the Lake Champlain Basin. Environ Manag 20:731–739

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Wilson HW, Xenopoulos MA (2008) Ecosystem and seasonal control of stream dissolved organic carbon along a gradient of agricultural land use. Ecosystems 11:555–568

Teague, Kenneth

From: Kwok, Rose
Sent: Monday, October 20, 2014 1:28 PM
To: Teague, Kenneth
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Attachments: SignedElevation.pdf; SWG-2011-00591Rademacher SS.doc; Signed_Elevation_Request.pdf

-----Original Message-----
From: Teague, Kenneth
Sent: Monday, October 20, 2014 2:14 PM
To: Kwok, Rose
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Rose- I left you a voice mail about this. We are probably going to elevate this one. Do you have one of Jim Herrington's JD elevation letters? I could use an example. Thanks.

-----Original Message-----
From: Teague, Kenneth
Sent: Thursday, October 09, 2014 2:00 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

fyi

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I think we did address these 51.

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Folks;

Please note there is a typographical error in the last sentence of the 5th paragraph and is should read.........

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are NOT waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

Thanks
Kenny Jaynes

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG
Sent: Tuesday, October 07, 2014 12:13 PM
To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

NOTE: I will be out of the office from 8 Oct thru 20 Oct any questions need to be send to Mr. John Davidson.

Folks;

The purpose of this e-mail is to begin the coordination required for SWG draft non-jurisdictional determination for file SWG-2013-00982; for 51 isolated wetland polygons. This e-mail initiates the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations. NOTE: as of the date of this coordination much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

This approximate 370 acre project area is located east of Ellington Field in League City area of Harris County, Texas. The majority of the site has been landcleared and some detention basins have been constructed. This includes an appx 30 acre tract, located south of the pipeline easement that has not been landcleared. This small portion of the site has a mix of tallow dominated areas and open herbaceous seasonal prairie and has appx. 6 wetland polygons that total an appx 1.8 acres. This entire project area historically contained mostly upland prairie with a mix of seasonal depressional wetlands (some of which were dominated with tallow trees). It has been and continues to have portions being used for graze land. The source of hydrology for the wetlands on the site is precipitation. The wetland are seasonal and depressional. The soils are mapped as clay loams and clays; thus affecting lateral movement of shallow subsurface hydrology.

Since the majority of the site has been impacted by the mechanized land-clearing much of the extents of the wetlands were based upon off-site information in conjunction with four separate field visits conducted by the Corps. (NOTEWORTHY: a previous field visit was conducted by the Corps and EPA {Jim Herrington} to investigate a purported unauthorized activity which was found to not be an unauthorized activity.) The appx. wetland polygons and sizes varied from appx. 0.02 acre to greater than appx. 7 acres (noting greater than 80% are re less than an acre in size); with an estimated aggregate total of appx. 49 acres. The distance to the nearest water of the U.S. (a RPW of Horsepen Bayou) varied from appx. 0.4 mile to greater than 1.3 miles. The appx. distances to the nearest TNW (Armand Bayou) would be appx. 1.3 miles and the furthest would be appx. 2.2 miles. The entire site was examined and based on site information and off-site information there were not any confined surface hydrologic connections nor any shallow subsurface hydrologic connections (based on sampling) detected. All of these appx. 51 wetlands are located outside the anticipated high flow (above the 100-year flood plain of any water of the U.S.). If there were ever to occur any "fill and spill" that might provide hydrology to any waters of the U.S., it would have to be through overland sheet flow, and it would be for extremely brief and episodically events that would occur in extreme above normal circumstances/conditions.

Historically, there have been concerns expressed regarding the fact that recent scientific reports revealed that isolated (as per federal regulations) depressional seasonal wetlands similar to these, provide sinks that fixate N and P and/or effect the water budget; to address this concern it is SWG position that there are numerous other factors that also play into these determinations. Therefore, based on the fact that these geographically isolated wetland that are not "inseparably bound-up" to the nearest TNW, it would be purely speculative to state that the destruction of these wetlands would have more than speculative or insubstantial effect upon the chemical, physical and/or biological integrity of the nearest TNW located greater than 1 mile away.

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

These wetlands (as identified per the manual) are located outside any anticipated high flow (e.g. 100-yr floodplain) of any waters of the U.S., are surrounded by uplands, are not tidal, and are not located in an ecological landscape position that would be utilized for any known species in the geo-region that would require both the wetland and the water body to fulfill their life cycle requirements. These wetlands are located greater than a mile away from the nearest water body. There are not any surface hydrologic connections to any waters of the U.S., these wetlands are not located in a geomorphic position that is inseparably bound to any water of the U.S. nor is there any known biological species in this geo-region that requires both the wetland in review and the nearest TNW to full life cycle requirements.

Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

In conclusion, the Corps has verified that the majority of the site is uplands and there are some pockets of depressional seasonal wetlands on the tract by using on-site and off-site information per the appropriate manual. The wetlands are located in an "isolated" (as defined by federal regulation: 33 CFR 330.2 Definitions:(e) Isolated waters means those non-tidal waters of the U.S. that are:(1) Not part of a surface tributary system to interstate or navigable waters of the US; and (2) Not adjacent to such tributary waterbodies). There is no known nexus to interstate commerce associated with any of them. As such, it is the Corps draft determination that these wetlands would not be subject to federal jurisdiction under Section 404 of the Clean Water Act. Noting as of the date of this e-mail much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

Kenny Jaynes
SWG POC

Teague, Kenneth

From: Teague, Kenneth
Sent: Monday, October 20, 2014 2:48 PM
To: Parrish, Sharon
Subject: JD elevation

Sharon- I looked at the Rapanos Guidance, and based on that I recommend that you send an email to Kenny Jaynes. I think this is due tomorrow.

Dear Mr. Jaynes- Thank you for providing your e-mail of October 7, 2014 initiating the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations for "51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)". We elect to elevate the review to our Regional Administrator (RA) and so are notifying you in writing.

The rationale for EPA's position on this is based on: 1) We disagree that these wetlands are not adjacent to any Relatively Permanent Water (RPW); 2) We disagree that any potential hydrologic connection of these wetlands to an RPW and Traditional Navigable Water (TNW) would be limited to extreme events, and would be via overland flow only. We argue that these wetlands would likely be connected hydrologically to an RPW and TNW during higher rainfall events, and that such events are within the definition of "normal" environmental conditions for this region. We also believe that, in addition to overland flow, at least some of these wetlands are likely connected hydrologically during higher rainfall events, to an RPW and TNW, via swales. 3) While we agree that there are factors other than the water quality functions of wetlands that may play a role in determining whether or not a significant nexus exists between a wetland and an RPW and TNW, water quality alone can constitute such a significant nexus. It is not at clear from your email, that COE staff understand the water quality functions of these wetlands. Finally, we would like to reiterate comments that we have recently made on multiple JDs: There are several high quality peer-reviewed, published studies of very similar coastal Texas depressional wetlands' hydrology and water quality (Wilcox et al. 2011; Forbes et al. 2012), which document connectivity to downstream waters, as well as documenting a significant nexus between them and downstream waters, via their water quality functions. In this particular case, we believe these studies clearly apply, as the sites that were studied are very nearby and are very similar to those you have determined not to be jurisdictional.

All this said, in order to be consistent with recent similar EPA reviews of COE JD's, we must acknowledge that these reviews include considerable uncertainty. We have not visited the site and we have limited information to review. If you have any questions, please contact Mr. Kenneth Teague of my staff at (214) 665-6687.

Sincerely,

Sharon Fancy Parrish
Chief
Wetlands Section
EPA Region 6

References

Forbes, M. G., J. Back, and R. D. Doyle. 2012. "Nutrient Transformation and Retention by Coastal Prairie Wetlands, Upper Gulf Coast, Texas." *Wetlands*, 32(4), 705–715.

Wilcox, B. P., D. D. Dean, J. S. Jacob, and A. Sipocz. 2011. "Evidence of Surface Connectivity for Texas Gulf Coast Depressional Wetlands." *Wetlands*, 31(3), 451–458.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Monday, October 20, 2014 4:00 PM
To: Parrish, Sharon
Subject: JD Elevation

How's this?

Dear Mr. Jaynes- Thank you for providing your e-mail of October 7, 2014 initiating the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations for "51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)". We elect to elevate the review to our Regional Administrator (RA) and so are notifying you in writing.

The rationale for EPA's position on this is based on: 1) We believe that these wetlands are adjacent to a Relatively Permanent Water (RPW); 2) We believe that these wetlands would likely be connected hydrologically to an RPW and TNW during higher rainfall events, via overland flow and flow through swales and/or ditches, and that such events are within the definition of "normal" environmental conditions for this region. 3) While we agree that there are factors other than the water quality functions of wetlands that may play a role in determining whether or not a significant nexus exists between a wetland and an RPW and TNW, water quality alone can constitute such a significant nexus. Finally, we would like to reiterate that there are several high quality peer-reviewed, published studies of very similar coastal Texas depressional wetlands' hydrology and water quality (Wilcox et al. 2011; Forbes et al. 2012), which document connectivity to downstream waters, as well as a significant nexus between them and downstream waters via their water quality functions. In this particular case, we believe these studies clearly apply, as the sites that were studied are very nearby and are very similar to those you have determined not to be jurisdictional.

All this said, in order to be consistent with recent similar EPA reviews of COE JD's, we must acknowledge that these reviews include considerable uncertainty. We have not visited the site and we have limited information to review. If you have any questions, please contact Mr. Kenneth Teague of my staff at (214) 665-6687.

Sincerely,

Sharon Fancy Parrish
Chief
Wetlands Section
EPA Region 6

References

Forbes, M. G., J. Back, and R. D. Doyle. 2012. "Nutrient Transformation and Retention by Coastal Prairie Wetlands, Upper Gulf Coast, Texas." *Wetlands*, 32(4), 705–715.

Wilcox, B. P., D. D. Dean, J. S. Jacob, and A. Sipocz. 2011. "Evidence of Surface Connectivity for Texas Gulf Coast Depressional Wetlands." *Wetlands*, 31(3), 451–458.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Parrish, Sharon
Sent: Monday, October 20, 2014 4:08 PM
To: Kenny Jaynes
Cc: Teague, Kenneth
Subject: FW: JD Elevation

Dear Kenny - Thank you for providing your e-mail of October 7, 2014 initiating the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations for “51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)”. We elect to elevate the review to our Regional Administrator (RA) and so are notifying you in writing.

The rationale for EPA’s position on this is based on: 1) We believe that these wetlands are adjacent to a Relatively Permanent Water (RPW); 2) We believe that these wetlands would likely be connected hydrologically to an RPW and TNW during higher rainfall events, via overland flow and flow through swales and/or ditches, and that such events are within the definition of “normal” environmental conditions for this region. 3) While we agree that there are factors other than the water quality functions of wetlands that may play a role in determining whether or not a significant nexus exists between a wetland and an RPW and TNW, water quality alone can constitute such a significant nexus. Finally, we would like to reiterate that there are several high quality peer-reviewed, published studies of very similar coastal Texas depressional wetlands’ hydrology and water quality (Wilcox et al. 2011; Forbes et al. 2012), which document connectivity to downstream waters, as well as a significant nexus between them and downstream waters via their water quality functions. In this particular case, we believe these studies clearly apply, as the sites that were studied are very nearby and are very similar to those you have determined not to be jurisdictional.

All this said, in order to be consistent with recent similar EPA reviews of COE JD’s, we must acknowledge that these reviews include some uncertainty. We have not visited the site and we have limited information to review. If you have any questions, please contact Mr. Kenneth Teague of my staff at (214) 665-6687.

Sincerely,

Sharon Fancy Parrish
Chief
Wetlands Section
EPA Region 6

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Forbes, M. G., J. Back, and R. D. Doyle. 2012. “Nutrient Transformation and Retention by Coastal Prairie Wetlands, Upper Gulf Coast, Texas.” *Wetlands*, 32(4), 705–715.

Wilcox, B. P., D. D. Dean, J. S. Jacob, and A. Sipocz. 2011. “Evidence of Surface Connectivity for Texas Gulf Coast Depressional Wetlands.” *Wetlands*, 31(3), 451–458.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
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1445 Ross Ave, Suite 1200 (6WQ-EM)
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FAX: 214-665-6689

Teague, Kenneth

From: Parrish, Sharon
Sent: Monday, October 20, 2014 4:08 PM
To: Kenny Jaynes
Cc: Teague, Kenneth
Subject: FW: JD Elevation

Dear Kenny - Thank you for providing your e-mail of October 7, 2014 initiating the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations for “51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)”. We elect to elevate the review to our Regional Administrator (RA) and so are notifying you in writing.

The rationale for EPA’s position on this is based on: 1) We believe that these wetlands are adjacent to a Relatively Permanent Water (RPW); 2) We believe that these wetlands would likely be connected hydrologically to an RPW and TNW during higher rainfall events, via overland flow and flow through swales and/or ditches, and that such events are within the definition of “normal” environmental conditions for this region. 3) While we agree that there are factors other than the water quality functions of wetlands that may play a role in determining whether or not a significant nexus exists between a wetland and an RPW and TNW, water quality alone can constitute such a significant nexus. Finally, we would like to reiterate that there are several high quality peer-reviewed, published studies of very similar coastal Texas depressional wetlands’ hydrology and water quality (Wilcox et al. 2011; Forbes et al. 2012), which document connectivity to downstream waters, as well as a significant nexus between them and downstream waters via their water quality functions. In this particular case, we believe these studies clearly apply, as the sites that were studied are very nearby and are very similar to those you have determined not to be jurisdictional.

All this said, in order to be consistent with recent similar EPA reviews of COE JD’s, we must acknowledge that these reviews include some uncertainty. We have not visited the site and we have limited information to review. If you have any questions, please contact Mr. Kenneth Teague of my staff at (214) 665-6687.

Sincerely,

Sharon Fancy Parrish
Chief
Wetlands Section
EPA Region 6

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Forbes, M. G., J. Back, and R. D. Doyle. 2012. “Nutrient Transformation and Retention by Coastal Prairie Wetlands, Upper Gulf Coast, Texas.” *Wetlands*, 32(4), 705–715.

Wilcox, B. P., D. D. Dean, J. S. Jacob, and A. Sipocz. 2011. “Evidence of Surface Connectivity for Texas Gulf Coast Depressional Wetlands.” *Wetlands*, 31(3), 451–458.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
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Teague, Kenneth

Subject: JD discussion
Location: I'll call you

Start: Tue 10/21/2014 3:30 PM
End: Tue 10/21/2014 4:00 PM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Kwok, Rose
Required Attendees: Teague, Kenneth

Ken – any chance you are free at this time to chat about the JD? I'm so sorry that I didn't call you yesterday – I've had meetings practically all day today and yesterday.

Thanks – I can call you!

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 21, 2014 8:49 AM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: FW: JD Elevation

From: Parrish, Sharon
Sent: Monday, October 20, 2014 4:08 PM
To: Kenny Jaynes
Cc: Teague, Kenneth
Subject: FW: JD Elevation

Dear Kenny - Thank you for providing your e-mail of October 7, 2014 initiating the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations for "51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)". We elect to elevate the review to our Regional Administrator (RA) and so are notifying you in writing.

The rationale for EPA's position on this is based on: 1) We believe that these wetlands are adjacent to a Relatively Permanent Water (RPW); 2) We believe that these wetlands would likely be connected hydrologically to an RPW and TNW during higher rainfall events, via overland flow and flow through swales and/or ditches, and that such events are within the definition of "normal" environmental conditions for this region. 3) While we agree that there are factors other than the water quality functions of wetlands that may play a role in determining whether or not a significant nexus exists between a wetland and an RPW and TNW, water quality alone can constitute such a significant nexus. Finally, we would like to reiterate that there are several high quality peer-reviewed, published studies of very similar coastal Texas depressional wetlands' hydrology and water quality (Wilcox et al. 2011; Forbes et al. 2012), which document connectivity to downstream waters, as well as a significant nexus between them and downstream waters via their water quality functions. In this particular case, we believe these studies clearly apply, as the sites that were studied are very nearby and are very similar to those you have determined not to be jurisdictional.

All this said, in order to be consistent with recent similar EPA reviews of COE JD's, we must acknowledge that these reviews include some uncertainty. We have not visited the site and we have limited information to review. If you have any questions, please contact Mr. Kenneth Teague of my staff at (214) 665-6687.

Sincerely,

Sharon Fancy Parrish
Chief
Wetlands Section
EPA Region 6

References

Forbes, M. G., J. Back, and R. D. Doyle. 2012. "Nutrient Transformation and Retention by Coastal Prairie Wetlands, Upper Gulf Coast, Texas." *Wetlands*, 32(4), 705–715.

Wilcox, B. P., D. D. Dean, J. S. Jacob, and A. Sipocz. 2011. "Evidence of Surface Connectivity for Texas Gulf Coast Depressional Wetlands." *Wetlands*, 31(3), 451–458.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 21, 2014 12:37 PM
To: Kwok, Rose
Subject: Accepted: JD discussion

Teague, Kenneth

From:	Teague, Kenneth
Sent:	Tuesday, October 21, 2014 12:52 PM
To:	Kwok, Rose
Cc:	Parrish, Sharon
Subject:	JD SWG-2013-00982
Attachments:	hcfcdmodeldownload1.pdf; hcfcdmodeldownload2.pdf; tx_horsepen bayour.pdf; usgsdrainage1.pdf; Trendmaker.pdf; Trendmaker2.pdf

Some additional information I have collected. There are some more files in my folder, but I think those were attached to the email, so you should have them.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Kwok, Rose
Sent: Wednesday, October 22, 2014 11:24 AM
To: Parrish, Sharon; Teague, Kenneth
Subject: Question re: the 51 wetland site

I just had a very quick talk with Russ, and he wanted to know if the Region would be willing to pursue an enforcement action should the wetlands be called jurisdictional. Since the wetlands have already been filled, I think this is a critical piece of information to know.

Thanks!

Rose

Rose Kwok
U.S. Environmental Protection Agency
Wetlands Division
kwok.rose@epa.gov
202-566-0657, 202-566-1375 (fax)

Teague, Kenneth

From: Teague, Kenneth
Sent: Wednesday, October 22, 2014 4:02 PM
To: Parrish, Sharon
Subject: draft elevation memo
Attachments: MEMORANDUM JD elevations 102214.doc

I'll need to draft a supporting document explaining my rationale for why I think they may be jurisdictional.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 8:59 AM
To: Jaynes, Kenneth E (Kenny) SWG
Subject: SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Kenny- Is there a contractor report on this site? If so, who can I contact to request a copy? Thanks.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 9:25 AM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Attachments: coe email.pdf; Isolated Wetlands SWG-2013-00982 Trendmaker Homes.pdf; nwi1.pdf; Trendmaker.pdf; Trendmaker2.pdf; floodplain1.tif; floodplain2.tif; usgsdrainage1.pdf; hcfcdmodeldownload1.pdf; hcfcdmodeldownload2.pdf; IMG_0428.JPG; IMG_0442.JPG; Pothole panorama.jpg; swale 60 ft upstream of weir.jpg; trib near head w wrack lines.jpg; ab_wpp_armand_bayou.pdf; elevationemail.pdf; Coastal-Pothole-Wetland-Factsheet.pdf; 2011evidence-of-surface-connectivity-for-texas-gulf-coast-depressional-wetlands.pdf; Forbes et al. 2012.pdf; forbes and doyle.pdf; hydrology of coastal prairie freshwater wetlands.pdf; GIS Tx isolated wetlands.pdf; Sipocz.pdf; SipoczFullPaper.pdf

Hi Rose- I know I must have sent you some things about this, but now I can't find that I did, so I'm resending you everything I have since we may be elevating this to you (if the RA signs the memo by Thursday). The photos are not of the site, but rather, of other nearby, similar coastal prairie pothole wetlands. They were provided by John Jacobs. Andy Sipocz is the man in the photos. I also have a jpg of LIDAR data, but the file is too large to send with this email. I'll try to resend in a separate email.

Kenneth Teague, PWS, Certified Senior Ecologist Environmental Scientist Wetlands Section EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

-----Original Message-----
From: Teague, Kenneth
Sent: Monday, October 20, 2014 1:28 PM
To: Kwok, Rose
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Thanks Rose.

-----Original Message-----
From: Kwok, Rose
Sent: Monday, October 20, 2014 1:28 PM
To: Teague, Kenneth
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

-----Original Message-----
From: Teague, Kenneth
Sent: Monday, October 20, 2014 2:14 PM
To: Kwok, Rose
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Rose- I left you a voice mail about this. We are probably going to elevate this one. Do you have one of Jim Herrington's JD elevation letters? I could use an example. Thanks.

-----Original Message-----
From: Teague, Kenneth
Sent: Thursday, October 09, 2014 2:00 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

fyi

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I think we did address these 51.

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Folks;

Please note there is a typographical error in the last sentence of the 5th paragraph and is should read.........

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are NOT waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

Thanks
Kenny Jaynes

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG
Sent: Tuesday, October 07, 2014 12:13 PM
To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

NOTE: I will be out of the office from 8 Oct thru 20 Oct any questions need to be send to Mr. John Davidson.

Folks;

The purpose of this e-mail is to begin the coordination required for SWG draft non-jurisdictional determination for file SWG-2013-00982; for 51 isolated wetland polygons. This e-mail initiates the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations. NOTE: as of the date of this coordination much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

This approximate 370 acre project area is located east of Ellington Field in League City area of Harris County, Texas. The majority of the site has been landcleared and some detention basins have been constructed. This includes an appx 30 acre tract, located south of the pipeline easement that has not been landcleared. This small portion of the site has a mix of tallow dominated areas and open herbaceous seasonal prairie and has appx. 6 wetland polygons that total an appx 1.8 acres. This entire project area historically contained mostly upland prairie with a mix of seasonal depressional wetlands (some of which were dominated with tallow trees). It has been and continues to have portions being used for graze land. The source of hydrology for the wetlands on the site is precipitation. The wetland are seasonal and depressional. The soils are mapped as clay loams and clays; thus affecting lateral movement of shallow subsurface hydrology.

Since the majority of the site has been impacted by the mechanized land-clearing much of the extents of the wetlands were based upon off-site information in conjunction with four separate field visits conducted by the Corps. (NOTEWORTHY: a previous field visit was conducted by the Corps and EPA {Jim Herrington} to investigate a purported unauthorized activity which was found to not be an unauthorized activity.) The appx. wetland polygons and sizes varied from appx. 0.02 acre to greater than appx. 7 acres (noting greater than 80% are re less than an acre in size); with an estimated aggregate total of appx. 49 acres. The distance to the nearest water of the U.S. (a RPW of Horsepen Bayou) varied from appx. 0.4 mile to greater than 1.3 miles. The appx. distances to the nearest TNW (Armand Bayou) would be appx. 1.3 miles and the furthest would be appx. 2.2 miles. The entire site was examined and based on site information and off-site information there were not any confined surface hydrologic connections nor any shallow subsurface hydrologic connections (based on sampling) detected. All of these appx. 51 wetlands are located outside the anticipated high flow (above the 100-year flood plain of any water of the U.S.). If there were ever to occur any "fill and spill" that might provide hydrology to any waters of the U.S., it would have to be through overland sheet flow, and it would be for extremely brief and episodically events that would occur in extreme above normal circumstances/conditions.

Historically, there have been concerns expressed regarding the fact that recent scientific reports revealed that isolated (as per federal regulations) depressional seasonal wetlands similar to these, provide sinks that fixate N and P and/or effect the water budget; to address this concern it is SWG position that there are numerous other factors that also play into these determinations. Therefore, based on the fact that these geographically isolated wetland that are not "inseparably bound-up" to the nearest TNW, it would be purely speculative to state that the destruction of these wetlands would have more than speculative or insubstantial effect upon the chemical, physical and/or biological integrity of the nearest TNW located greater than 1 mile away.

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

These wetlands (as identified per the manual) are located outside any anticipated high flow (e.g. 100-yr floodplain) of any waters of the U.S., are surrounded by uplands, are not tidal, and are not located in an ecological landscape position that would be utilized for any known species in the geo-region that would require both the wetland and the water body to fulfill their life cycle requirements. These wetlands are located greater than a mile away from the nearest water body. There are not any surface hydrologic connections to any waters of the U.S., these wetlands are not located in a geomorphic position that is inseparably bound to any water of the U.S. nor is there any known biological species in this geo-region that requires both the wetland in review and the nearest TNW to full life cycle requirements.

Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

In conclusion, the Corps has verified that the majority of the site is uplands and there are some pockets of depressional seasonal wetlands on the tract by using on-site and off-site information per the appropriate manual. The wetlands are located in an "isolated" (as defined by federal regulation: 33 CFR 330.2 Definitions:(e) Isolated waters means those non-tidal waters of the U.S. that are:(1) Not part of a surface tributary system to interstate or navigable waters of the US; and (2) Not adjacent to such tributary waterbodies). There is no known nexus to interstate commerce associated with any of them. As such, it is the Corps draft determination that these wetlands would not be subject to federal jurisdiction under Section 404 of the Clean Water Act. Noting as of the date of this e-mail much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

Kenny Jaynes
SWG POC

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 9:31 AM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Attachments: coe email.pdf; Isolated Wetlands SWG-2013-00982 Trendmaker Homes.pdf; nwi1.pdf; Trendmaker.pdf; Trendmaker2.pdf; floodplain1.tif; floodplain2.tif; usgsdrainage1.pdf; hcfcdmodeldownload1.pdf; hcfcdmodeldownload2.pdf; IMG_0428.JPG; IMG_0442.JPG; Pothole panorama.jpg; swale 60 ft upstream of weir.jpg; trib near head w wrack lines.jpg; elevationemail.pdf; Coastal-Pothole-Wetland-Factsheet.pdf; 2011evidence-of-surface-connectivity-for-texas-gulf-coast-depressional-wetlands.pdf; Forbes et al. 2012.pdf; forbes and doyle.pdf; hydrology of coastal prairie freshwater wetlands.pdf; GIS Tx isolated wetlands.pdf; Sipocz.pdf; SipoczFullPaper.pdf

Apparently this didn't go through, so I removed a file and am resending.

-----Original Message-----
From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 9:21 AM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Rose- I know I must have sent you some things about this, but now I can't find that I did, so I'm resending you everything I have since we may be elevating this to you (if the RA signs the memo by Thursday). The photos are not of the site, but rather, of other nearby, similar coastal prairie pothole wetlands. They were provided by John Jacobs. Andy Sipocz is the man in the photos. I also have a jpg of LIDAR data, but the file is too large to send with this email. I'll try to resend in a separate email.

Kenneth Teague, PWS, Certified Senior Ecologist Environmental Scientist Wetlands Section EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

-----Original Message-----
From: Teague, Kenneth
Sent: Monday, October 20, 2014 1:28 PM
To: Kwok, Rose
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Thanks Rose.

-----Original Message-----
From: Kwok, Rose
Sent: Monday, October 20, 2014 1:28 PM
To: Teague, Kenneth
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

-----Original Message-----
From: Teague, Kenneth
Sent: Monday, October 20, 2014 2:14 PM
To: Kwok, Rose
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Rose- I left you a voice mail about this. We are probably going to elevate this one. Do you have one of Jim Herrington's JD elevation letters? I could use an example. Thanks.

-----Original Message-----
From: Teague, Kenneth
Sent: Thursday, October 09, 2014 2:00 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

fyi

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I think we did address these 51.

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Folks;

Please note there is a typographical error in the last sentence of the 5th paragraph and is should read.........

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are NOT waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

Thanks
Kenny Jaynes

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG
Sent: Tuesday, October 07, 2014 12:13 PM

To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

NOTE: I will be out of the office from 8 Oct thru 20 Oct any questions need to be send to Mr. John Davidson.

Folks;

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Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

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Kenny Jaynes
SWG POC

Teague, Kenneth

From: Jaynes, Kenneth E (Kenny) SWG <Kenny.Jaynes@usace.army.mil>
Sent: Tuesday, October 28, 2014 9:50 AM
To: Teague, Kenneth
Cc: Mattox, Sharon; Shivers, Kristin D SWG; Davidson, John SWG; McLaughlin, Kimberly SWG
Subject: RE: SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Ken;

The point of contact for this determination is Trendmaker's legal counsel: Ms. Sharon Mattox at 713-874-9696; I have copy furnished her on this e-mail also so you have an e-mail contact address.

We have received EPA's notification of elevation of the JD to the RA on 20 October 2014 and are acting accordingly.

V/R

Kenny Jaynes

-----Original Message-----
From: Teague, Kenneth [mailto:teague.kenneth@epa.gov]
Sent: Tuesday, October 28, 2014 8:59 AM
To: Jaynes, Kenneth E (Kenny) SWG
Subject: [EXTERNAL] SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Kenny- Is there a contractor report on this site? If so, who can I contact to request a copy? Thanks.

Kenneth Teague, PWS, Certified Senior Ecologist Environmental Scientist

Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Jaynes, Kenneth E (Kenny) SWG <Kenny.Jaynes@usace.army.mil>
Sent: Tuesday, October 28, 2014 9:52 AM
To: Teague, Kenneth; Parrish, Sharon
Cc: Shivers, Kristin D SWG; Davidson, John SWG; Dixon, Vicki G SWD; Pannell, Richard P COL SWG; Jensen, Stacey M HQ02; McLaughlin, Kimberly SWG
Subject: Trendmaker JD

Ken and Sharon;

We are still awaiting notification from the EPA Region VI confirming that EPA Region VI RA has accepted this jurisdictional determination (JD) elevation (please advise).

However, as discussed subsequent to the 20 October 2014 notification of elevation of this JD and in full accordance with the Rapanos guidance for JD (specifically "Memorandum for Director of Civil Works and US EPA Regional Administrator" dated 5 June 2007), the Corps District (SWG) has continued to move forward for this next level of review and briefed our Commander and informed Corps HQ of this JD elevation. NOTE: The mandated 10 day time frame for review at this level of elevation expires on 30 October 2014.

As of this time and based on our interactions with our commander (Colonel Pannell) SWG position on this JD remains the same as submitted: our jurisdictional determination is there are wetlands on the Trendmaker site and these wetlands are isolated non-jurisdictional and are not subject to federal regulations under Section 404 of the Clean Water Act

We continue to move forward on this action accordingly.

V/R

Kenny Jaynes
409-766-3985

Teague, Kenneth

From: Jaynes, Kenneth E (Kenny) SWG <Kenny.Jaynes@usace.army.mil>
Sent: Tuesday, October 28, 2014 9:54 AM
To: Jaynes, Kenneth E (Kenny) SWG; Teague, Kenneth
Cc: Shivers, Kristin D SWG; Davidson, John SWG; McLaughlin, Kimberly SWG; s.mattox@smattoxlaw.com
Subject: RE: SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Ken:

I got a bounce back and noted that Ms. Mattox e-mail on the original e-mail is not correct it is:

s.mattox@smattoxlaw.com

Thanks
Kenny

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG
Sent: Tuesday, October 28, 2014 9:50 AM
To: 'Teague, Kenneth'
Cc: 'Mattox, Sharon'; Shivers, Kristin D SWG; Davidson, John SWG; McLaughlin, Kimberly SWG
Subject: RE: SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Ken;

The point of contact for this determination is Trendmaker's legal counsel: Ms. Sharon Mattox at 713-874-9696; I have copy furnished her on this e-mail also so you have an e-mail contact address.

We have received EPA's notification of elevation of the JD to the RA on 20 October 2014 and are acting accordingly.

V/R

Kenny Jaynes

-----Original Message-----
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Sent: Tuesday, October 28, 2014 8:59 AM
To: Jaynes, Kenneth E (Kenny) SWG
Subject: [EXTERNAL] SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Kenny- Is there a contractor report on this site? If so, who can I contact to request a copy? Thanks.

Kenneth Teague, PWS, Certified Senior Ecologist Environmental Scientist

Wetlands Section

EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 12:00 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: FW: Trendmaker JD

Rose- The memo went to the Division Director yesterday. I'll ask where it is today.

Ken Teague

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 28, 2014 9:52 AM
To: Teague, Kenneth; Parrish, Sharon
Cc: Shivers, Kristin D SWG; Davidson, John SWG; Dixon, Vicki G SWD; Pannell, Richard P COL SWG; Jensen, Stacey M HQ02; McLaughlin, Kimberly SWG
Subject: Trendmaker JD

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We are still awaiting notification from the EPA Region VI confirming that EPA Region VI RA has accepted this jurisdictional determination (JD) elevation (please advise).

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As of this time and based on our interactions with our commander (Colonel Pannell) SWG position on this JD remains the same as submitted: our jurisdictional determination is there are wetlands on the Trendmaker site and these wetlands are isolated non-jurisdictional and are not subject to federal regulations under Section 404 of the Clean Water Act

We continue to move forward on this action accordingly.

V/R

Kenny Jaynes
409-766-3985

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 12:01 PM
To: Jaynes, Kenneth E (Kenny) SWG
Cc: Parrish, Sharon; Kwok, Rose
Subject: RE: Trendmaker JD

Kenny- The memo is in routing for signature. We'll just have to see if it makes it in time, and if the RA signs it.

Ken Teague

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 28, 2014 9:52 AM
To: Teague, Kenneth; Parrish, Sharon
Cc: Shivers, Kristin D SWG; Davidson, John SWG; Dixon, Vicki G SWD; Pannell, Richard P COL SWG; Jensen, Stacey M HQ02; McLaughlin, Kimberly SWG
Subject: Trendmaker JD

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We continue to move forward on this action accordingly.

V/R

Kenny Jaynes
409-766-3985

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 12:24 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: Email #2: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Attachments: tx_horsepen bayour.pdf

Hopefully you got the previous email with many attachments. I'm not sure because there was definitely a problem with my first attempt. I removed some files and resent it. I'm now trying to forward the files I removed. It looks like I will have to send them individually though, so expect more emails.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 12:27 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: Email #3: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Attachments: ab_wpp_armand_bayou.pdf

This is a watershed plan for the watershed these wetlands drain into, or don't drain into, depending on your perspective.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, October 28, 2014 12:45 PM
To: Parrish, Sharon
Subject: FW: Trendmaker JD

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 28, 2014 12:43 PM
To: Teague, Kenneth
Cc: McLaughlin, Kimberly SWG
Subject: RE: Trendmaker JD

Ken;

Please let us know ASAP the result of this memo; it will be a very aggressive interaction if the RA plans to initiate any discussions with our commander by the 30 deadline. - I will be out of the office on the 30th and 31st so please contact Ms. Kim McLaughlin Regulatory Division Chief on that date (I have cf her this e-mail).

Thanks
Kenny

P.S. EPA has been on the site earlier this year: Mr. Herrington

-----Original Message-----
From: Teague, Kenneth [mailto:teague.kenneth@epa.gov]
Sent: Tuesday, October 28, 2014 12:01 PM
To: Jaynes, Kenneth E (Kenny) SWG
Cc: Parrish, Sharon; Kwok, Rose
Subject: [EXTERNAL] RE: Trendmaker JD

Kenny- The memo is in routing for signature. We'll just have to see if it makes it in time, and if the RA signs it.

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Subject: Trendmaker JD

Ken and Sharon;

We are still awaiting notification from the EPA Region VI confirming that EPA Region VI RA has accepted this jurisdictional determination (JD) elevation (please advise).

However, as discussed subsequent to the 20 October 2014 notification of elevation of this JD and in full accordance with the Rapanos guidance for JD (specifically "Memorandum for Director of Civil Works and US EPA Regional Administrator" dated 5 June 2007), the Corps District (SWG) has continued to move forward for this next level of review and briefed our Commander and informed Corps HQ of this JD elevation. NOTE: The mandated 10 day time frame for review at this level of elevation expires on 30 October 2014.

As of this time and based on our interactions with our commander (Colonel Pannell) SWG position on this JD remains the same as submitted: our jurisdictional determination is there are wetlands on the Trendmaker site and these wetlands are isolated non-jurisdictional and are not subject to federal regulations under Section 404 of the Clean Water Act

We continue to move forward on this action accordingly.

V/R

Kenny Jaynes
409-766-3985

Teague, Kenneth

From: Jaynes, Kenneth E (Kenny) SWG <Kenny.Jaynes@usace.army.mil>
Sent: Friday, October 31, 2014 8:05 AM
To: Teague, Kenneth; Goodin, John; Parrish, Sharon; Curry, Ron; Coleman, Sam
Cc: Pannell, Richard P COL SWG; Kwok, Rose; Kitto, Alison; Jensen, Stacey M HQ02; McLaughlin, Kimberly SWG; Dixon, Vicki G SWD; Shivers, Kristin D SWG; Davidson, John SWG
Subject: RE: Elevation of Jurisdictional Determination SWG-2013-00982

Mr. Teague, et al;

Thanks for the copies of the elevation information associated with this jurisdictional determination from EPA Region VI (below) and the Corps will be moving forward with the status being as of the date of this notification: this jurisdictional determination has been elevated to the EPA HQ and Corps HQ level to address and finalize.

It is important to note, as previous communicated, that this jurisdictional determination coordination action is NOT associated with a Department of the Army permit application (as indicated in the 29 Oct 2014 EPA memo) but is associated with investigation of a purported non-permitted discharge of dredged and/or fill material into waters of the United States under Section 404 of the Clean Water Act.

These construction activities continue and are still on-going as of the date of this e-mail; and the vast majority (if not all of the wetlands) have been fill and/or excavated. As indicated in the jurisdictional coordination SWG's position associated with this investigation is there are not any "waters of the United States" on the tract that have been filled and as such a violation of Section 404 of the Clean Water Act has not occurred; therefore a notice of non-permit violation was not sent. However, in full accordance with rules and regulations, EPA has the ability and can assume the role of the lead federal agency associated with this non-permit investigation/enforcement action immediately.

If you have any questions please contact me.

V/R

Kenny Jaynes
Chief, Compliance Branch
Galveston, District
409-766-3985

-----Original Message-----
From: Teague, Kenneth [mailto:teague.kenneth@epa.gov]
Sent: Thursday, October 30, 2014 11:06 AM
To: Goodin, John
Cc: Pannell, Richard P COL SWG; Kwok, Rose; Jaynes, Kenneth E (Kenny) SWG; Parrish, Sharon; Kitto, Alison
Subject: [EXTERNAL] Elevation of Jurisdictional Determination SWG-2013-00982

Please find attached, a memo (filename=signed memo) elevating this JD to EPA Headquarters. I have also included the attachments to the memo. The following files are considered "Attachment 2": coe email.pdf, JDform.pdf, elevatinemail.pdf. I have also sent additional supporting information to Rose Kwop via separate email. Please call me if you have any questions.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist

Wetlands Section
EPA Region 6
1445 Ross Ave, Suite 1200 (6WQ-EM)
Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Parrish, Sharon
Sent: Wednesday, October 29, 2014 4:13 PM
To: Kenny Jaynes
Cc: Teague, Kenneth; Kwok, Rose
Subject: Jurisdictional determinations - 51 wetlands

Our memo from the RA to EPA HQ was signed today.

Teague, Kenneth

From: Teague, Kenneth
Sent: Monday, November 03, 2014 12:10 PM
To: Kwok, Rose
Subject: JD Elevation

Hi Rose- I'm assuming you guys received the JD we elevated last week? I'll also forward an email that Kenny Jaynes sent.

Kenneth Teague, PWS, Certified Senior Ecologist
Environmental Scientist
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Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Kwok, Rose
Sent: Tuesday, November 04, 2014 10:13 AM
To: Teague, Kenneth
Subject: RE: JD Elevation

Hi Ken,

Let's try to talk today – sorry, it's been crazy here!

From: Teague, Kenneth
Sent: Monday, November 03, 2014 1:10 PM
To: Kwok, Rose
Subject: JD Elevation

Hi Rose- I'm assuming you guys received the JD we elevated last week? I'll also forward an email that Kenny Jaynes sent.

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phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Kwok, Rose
Sent: Tuesday, November 04, 2014 10:17 AM
To: Teague, Kenneth
Subject: RE: JD Elevation

P.S. Were you ever able to speak to Jim?

From: Kwok, Rose
Sent: Tuesday, November 04, 2014 11:12 AM
To: Teague, Kenneth
Subject: RE: JD Elevation

Hi Ken,

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Sent: Monday, November 03, 2014 1:10 PM
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phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Tuesday, November 04, 2014 11:30 AM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: RE: JD Elevation

Yes, but he didn't have much to say about it. I don't think he was able to be sure that he knew which site we had elevated. I think his cell number is 254-654-1018 if you want to call him yourself. You may know better than I what kinds of questions you have for him. I would say though, that he generally supports our questioning the COE's JDs for Texas coastal prairie potholes, and specifically, their determinations that they are not jurisdictional.

Ken Teague

From: Kwok, Rose
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To: Teague, Kenneth
Subject: RE: JD Elevation

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Teague, Kenneth

From: Teague, Kenneth
Sent: Thursday, November 06, 2014 12:54 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: JD SWG-2013-00982 Supporting Argument
Attachments: SWG-2013-00982_draft_memo_.doc; coe email.pdf; JDform.pdf; nwi1.pdf; geomorphology.pdf; hcfcdmodeldownload1.pdf; hcfcdmodeldownload2.pdf; Trendmaker.pdf; Trendmaker2.pdf; Trendmaker3.pdf; usgsdrainage1.pdf; tx_horsepen bayour.pdf

Rose- I had a limited amount of time to do this additional work on the supporting argument in favor of EPA HQ reviewing the Galveston District's JD for this site. In addition, we have discussed that I am not yet familiar with some of the suttle legal arguments at play here. And again, we are doing all this from our desktop. At any rate, I took the paper you provided that you and Jim had presumably developed for the prairie pothole wetlands on the Ingleside Strandlplain, and simply began doing minor revisions to make it fit this case, while also trying to understand the various arguments that had been made, and determine whether or not they were applicable in this case. For the most part however, I assumed that most of the arguments did apply. Note also that I assumed that we could argue jurisdiction based on adjacency to either the TNW (Armand Bayou) or the RPW (Horsepen Bayou). However, my limited understanding suggests to me that perhaps a different kind of nexus argument might need to be provided to support an argument of adjacency to the RPW? Check me on this. I also used scientific citation style, while the original paper used footnotes, and now it contains both styles- this will obviously have to be changed. I also have not yet analyzed the rainfall data, however, I think the analysis done by Wilcox et al. (2011) could be adopted. If not, I could still do it if I have a couple of days to do so. I also need to number my figures. I will be out until next Wed.

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Dallas, TX 75202
phone: 214-665-6687
FAX: 214-665-6689

Teague, Kenneth

From: Teague, Kenneth
Sent: Thursday, November 06, 2014 12:57 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: JD
Attachments: IMG_0428.JPG; IMG_0442.JPG; Pothole panorama.jpg; swale 60 ft upstream of weir.jpg; trib near head w wrack lines.jpg; soilmap.pdf

These wouldn't fit on the previous email. I probably won't use all the files I sent. I need to select the ones to match up with the figures I cited in the text. I also need to draft a references cited section for the paper, or somehow include that in the footnote format.

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Teague, Kenneth

From:	Kwok, Rose
Sent:	Thursday, November 06, 2014 1:01 PM
To:	Teague, Kenneth
Cc:	Parrish, Sharon
Subject:	RE: JD

Ken,

Where are these photos from?

From: Teague, Kenneth
Sent: Thursday, November 06, 2014 1:57 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: JD

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Teague, Kenneth

From: Teague, Kenneth
Sent: Wednesday, November 12, 2014 7:47 AM
To: Kwok, Rose
Subject: RE: JD

I had previously sent you these photos. They are not from the subject wetlands, but from nearby, similar wetlands. John Jacobs gave them to me. I believe at least some (if not all) are from the site discussed in Wilcox et al. (2011). I will ask him.

Ken

From: Kwok, Rose
Sent: Thursday, November 06, 2014 1:01 PM
To: Teague, Kenneth
Cc: Parrish, Sharon
Subject: RE: JD

Ken,

Where are these photos from?

From: Teague, Kenneth
Sent: Thursday, November 06, 2014 1:57 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: JD

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Teague, Kenneth

From: Teague, Kenneth
Sent: Wednesday, November 12, 2014 7:58 AM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: RE: JD

FYI, I asked one of our GIS analysts to estimate the distances from two points near the subject wetlands, which were two of the sites studied by Forbes et al. (2012). Forbes et al. (2012) site HA is 0.18 mi from the nearest wetland among the subject wetlands, and their site UH is 2.23 miles. I realize that doesn't mean that the subject wetlands are jurisdictional, but John Jacobs and others tell us that the subject wetlands were similar to those studied by Wilcox et al. (2011) and Forbes et al. (2012), and they are very close, which suggests to me that they may well have been similar.

Ken

From: Kwok, Rose
Sent: Thursday, November 06, 2014 1:01 PM
To: Teague, Kenneth
Cc: Parrish, Sharon
Subject: RE: JD

Ken,

Where are these photos from?

From: Teague, Kenneth
Sent: Thursday, November 06, 2014 1:57 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: JD

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Teague, Kenneth

From:	Teague, Kenneth
Sent:	Wednesday, November 12, 2014 12:14 PM
To:	Kwok, Rose
Cc:	Parrish, Sharon; Kitto, Alison
Subject:	RE: JD
Attachments:	2011evidence-of-surface-connectivity-for-texas-gulf-coast-depressional-wetlands.pdf

Rose- We talked about me possibly providing an analysis of the rainfall data from the vicinity of the subject wetlands, to support the claim that rainfall sufficient to produce flow out of the wetlands, into downstream waters (RPW, TNW), would be considered "normal". For starters at least, I recommend looking at Figures 3 and 4 from Wilcox et al. (2011). That information begins to address the question. I suppose though that an additional analysis may be helpful to help support the assertion. I will try to do more, time permitting.

From: Kwok, Rose
Sent: Thursday, November 06, 2014 1:01 PM
To: Teague, Kenneth
Cc: Parrish, Sharon
Subject: RE: JD

Ken,

Where are these photos from?

From: Teague, Kenneth
Sent: Thursday, November 06, 2014 1:57 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: JD

These wouldn't fit on the previous email. I probably won't use all the files I sent. I need to select the ones to match up with the figures I cited in the text. I also need to draft a references cited section for the paper, or somehow include that in the footnote format.

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Teague, Kenneth

From: Teague, Kenneth
Sent: Thursday, November 13, 2014 10:56 AM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: ABNC study site
Attachments: IMG_0442.JPG; IMG_0428.JPG; swale 60 ft upstream of weir.jpg; trib near head w wrack lines.jpg; Pothole panorama.jpg

Rose- Here are John Jacobs' notes on the photos he sent me. I have a call in to him to further clarify as well.

Ken

From: John Jacob [mailto:jjacob@tamu.edu]
Sent: Monday, October 20, 2014 4:38 PM
To: Teague, Kenneth
Subject: ABNC study site

0442—prairie pothole. Armand Bayou Nature Center—about 2 miles from TM site
0428—headwater wetland swales. These two photos from the TAMU study site at ABNC. Note the shallow swales. These convey water across the landscape, largely wetlands themselves
The 60ft upstream photo—clean conveyance of water. No bed and banks, but water clearly moves, spilling over from the wetland just upstream.
Pothole panorama—from the ABNC study site. Sugarcane plumegrass is the grass with the big heads--obligate

Teague, Kenneth

From: Teague, Kenneth
Sent: Thursday, November 13, 2014 12:17 PM
To: Kwok, Rose
Cc: Parrish, Sharon
Subject: FW: ABNC study site
Attachments: IMG_0442.JPG; IMG_0428.JPG; swale 60 ft upstream of weir.jpg; trib near head w wrack lines.jpg; Pothole panorama.jpg

Rose- I just spoke to John and he said all of these pictures are from the Armand Bayou Nature Center site, which was the study site in Wilcox et al. (2011). He also said they recently modeled runoff for the subject wetland site using SWATT and he's going to send us that. Finally, I also spoke with Jim Herrington about the site again, and this time I got a clear impression that he remembered the site well. I think he is going to call you about it.

Ken

From: John Jacob [mailto:jjacob@tamu.edu]
Sent: Monday, October 20, 2014 4:38 PM
To: Teague, Kenneth
Subject: ABNC study site

0442—prairie pothole. Armand Bayou Nature Center—about 2 miles from TM site
0428—headwater wetland swales. These two photos from the TAMU study site at ABNC. Note the shallow swales. These convey water across the landscape, largely wetlands themselves
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Pothole panorama—from the ABNC study site. Sugarcane plumegrass is the grass with the big heads--obligate

Teague, Kenneth

From: Teague, Kenneth
Sent: Monday, October 20, 2014 1:14 PM
To: Kwok, Rose
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Rose- I left you a voice mail about this. We are probably going to elevate this one. Do you have one of Jim Herrington's JD elevation letters? I could use an example. Thanks.

-----Original Message-----
From: Teague, Kenneth
Sent: Thursday, October 09, 2014 2:00 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

fyi

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I think we did address these 51.

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Folks;

Please note there is a typographical error in the last sentence of the 5th paragraph and is should read.........

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are NOT waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

Thanks
Kenny Jaynes

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG
Sent: Tuesday, October 07, 2014 12:13 PM
To: Isolated Waters; Parrish, Sharon

Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

NOTE: I will be out of the office from 8 Oct thru 20 Oct any questions need to be send to Mr. John Davidson.

Folks;

The purpose of this e-mail is to begin the coordination required for SWG draft non-jurisdictional determination for file SWG-2013-00982; for 51 isolated wetland polygons. This e-mail initiates the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations. NOTE: as of the date of this coordination much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

This approximate 370 acre project area is located east of Ellington Field in League City area of Harris County, Texas. The majority of the site has been landcleared and some detention basins have been constructed. This includes an appx 30 acre tract, located south of the pipeline easement that has not been landcleared. This small portion of the site has a mix of tallow dominated areas and open herbaceous seasonal prairie and has appx. 6 wetland polygons that total an appx 1.8 acres. This entire project area historically contained mostly upland prairie with a mix of seasonal depressional wetlands (some of which were dominated with tallow trees). It has been and continues to have portions being used for graze land. The source of hydrology for the wetlands on the site is precipitation. The wetland are seasonal and depressional. The soils are mapped as clay loams and clays; thus affecting lateral movement of shallow subsurface hydrology.

Since the majority of the site has been impacted by the mechanized land-clearing much of the extents of the wetlands were based upon off-site information in conjunction with four separate field visits conducted by the Corps. (NOTEWORTHY: a previous field visit was conducted by the Corps and EPA {Jim Herrington} to investigate a purported unauthorized activity which was found to not be an unauthorized activity.) The appx. wetland polygons and sizes varied from appx. 0.02 acre to greater than appx. 7 acres (noting greater than 80% are re less than an acre in size); with an estimated aggregate total of appx. 49 acres. The distance to the nearest water of the U.S. (a RPW of Horsepen Bayou) varied from appx. 0.4 mile to greater than 1.3 miles. The appx. distances to the nearest TNW (Armand Bayou) would be appx. 1.3 miles and the furthest would be appx. 2.2 miles. The entire site was examined and based on site information and off-site information there were not any confined surface hydrologic connections nor any shallow subsurface hydrologic connections (based on sampling) detected. All of these appx. 51 wetlands are located outside the anticipated high flow (above the 100-year flood plain of any water of the U.S.). If there were ever to occur any "fill and spill" that might provide hydrology to any waters of the U.S., it would have to be through overland sheet flow, and it would be for extremely brief and episodically events that would occur in extreme above normal circumstances/conditions.

Historically, there have been concerns expressed regarding the fact that recent scientific reports revealed that isolated (as per federal regulations) depressional seasonal wetlands similar to these, provide sinks that fixate N and P and/or effect the water budget; to address this concern it is SWG position that there are numerous other factors that also play into these determinations. Therefore, based on the fact that these geographically isolated wetland that are not "inseparably bound-up" to the nearest TNW, it would be purely speculative to state that the destruction of these wetlands would have more than speculative or insubstantial effect upon the chemical, physical and/or biological integrity of the nearest TNW located greater than 1 mile away.

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

These wetlands (as identified per the manual) are located outside any anticipated high flow (e.g. 100-yr floodplain) of any waters of the U.S., are surrounded by uplands, are not tidal, and are not located in an ecological landscape position that would be utilized for any known species in the geo-region that would require both the wetland and the water body to fulfill their life cycle requirements. These wetlands are located greater than a mile away from the nearest water body. There are not any surface hydrologic connections to any waters of the U.S., these wetlands are not located in a geomorphic position that is inseparably bound to any water of the U.S. nor is there any known biological species in this geo-region that requires both the wetland in review and the nearest TNW to full life cycle requirements.

Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

In conclusion, the Corps has verified that the majority of the site is uplands and there are some pockets of depressional seasonal wetlands on the tract by using on-site and off-site information per the appropriate manual. The wetlands are located in an "isolated" (as defined by federal regulation: 33 CFR 330.2 Definitions:(e) Isolated waters means those non-tidal waters of the U.S. that are:(1) Not part of a surface tributary system to interstate or navigable waters of the US; and (2) Not adjacent to such tributary waterbodies). There is no known nexus to interstate commerce associated with any of them. As such, it is the Corps draft determination that these wetlands would not be subject to federal jurisdiction under Section 404 of the Clean Water Act. Noting as of the date of this e-mail much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

Kenny Jaynes
SWG POC

Teague, Kenneth

From: Kwok, Rose
Sent: Monday, October 20, 2014 1:21 PM
To: Teague, Kenneth
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

HI Ken,

Thanks, I got your message but have to run to a meeting. I'll forward you some of Jim's letters.

-----Original Message-----
From: Teague, Kenneth
Sent: Monday, October 20, 2014 2:14 PM
To: Kwok, Rose
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

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Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

fyi

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

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Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

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Kenny Jaynes

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To: Isolated Waters; Parrish, Sharon
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Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

NOTE: I will be out of the office from 8 Oct thru 20 Oct any questions need to be send to Mr. John Davidson.

Folks;

The purpose of this e-mail is to begin the coordination required for SWG draft non-jurisdictional determination for file SWG-2013-00982; for 51 isolated wetland polygons. This e-mail initiates the coordination process with the EPA as required by the Rapanos Guidance for finalizing jurisdictional determination for purposes of Section 404 of the Clean Water Act and "isolated" non-jurisdictional wetland determinations. NOTE: as of the date of this coordination much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

This approximate 370 acre project area is located east of Ellington Field in League City area of Harris County, Texas. The majority of the site has been landcleared and some detention basins have been constructed. This includes an appx 30 acre tract, located south of the pipeline easement that has not been landcleared. This small portion of the site has a mix of tallow dominated areas and open herbaceous seasonal prairie and has appx. 6 wetland polygons that total an appx 1.8 acres. This entire project area historically contained mostly upland prairie with a mix of seasonal depressional wetlands (some of which were dominated with tallow trees). It has been and continues to have portions being used for graze land. The source of hydrology for the wetlands on the site is precipitation. The wetland are seasonal and depressional. The soils are mapped as clay loams and clays; thus affecting lateral movement of shallow subsurface hydrology.

Since the majority of the site has been impacted by the mechanized land-clearing much of the extents of the wetlands were based upon off-site information in conjunction with four separate field visits conducted by the Corps. (NOTEWORTHY: a previous field visit was conducted by the Corps and EPA {Jim Herrington} to investigate a purported unauthorized activity which was found to not be an unauthorized activity.) The appx. wetland polygons and sizes varied from appx. 0.02 acre to greater than appx. 7 acres (noting greater than 80% are re less than an acre in size); with an estimated aggregate total of appx. 49 acres. The distance to the nearest water of the U.S. (a RPW of Horsepen Bayou) varied from appx. 0.4 mile to greater than 1.3 miles. The appx. distances to the nearest TNW (Armand Bayou) would be appx. 1.3 miles and the furthest would be appx. 2.2 miles. The entire site was examined and based on site information and off-site information there were not any confined surface hydrologic connections nor any shallow subsurface hydrologic connections (based on sampling) detected. All of these appx. 51 wetlands are located outside the anticipated high flow (above the 100-year flood plain of any water of the U.S.). If there were ever to occur any "fill and spill" that might provide hydrology to any waters of the U.S., it would have to be through overland sheet flow, and it would be for extremely brief and episodically events that would occur in extreme above normal circumstances/conditions.

Historically, there have been concerns expressed regarding the fact that recent scientific reports revealed that isolated (as per federal regulations) depressional seasonal wetlands similar to these, provide sinks that fixate N and P and/or effect the water budget; to address this concern it is SWG position that there are numerous other factors that also play into these determinations. Therefore, based on the fact that these geographically isolated wetland that are not "inseparably bound-up" to the nearest TNW, it would be purely speculative to state that the destruction of these wetlands would have more than speculative or insubstantial effect upon the chemical, physical and/or biological integrity of the nearest TNW located greater than 1 mile away.

This determination is based on off-site analysis, numerous site visit, LIDAR, review of the consultant report, rules and regulations; it is SWG position that while there are numerous wetlands (appx 51) they are "isolated" and do not have any no-known nexus to interstate commerce; as such, they are waters of the U.S. subject to federal jurisdiction under Section 404 of the Clean Water Act.

These wetlands (as identified per the manual) are located outside any anticipated high flow (e.g. 100-yr floodplain) of any waters of the U.S., are surrounded by uplands, are not tidal, and are not located in an ecological landscape position that would be utilized for any known species in the geo-region that would require both the wetland and the water body to fulfill their life cycle requirements. These wetlands are located greater than a mile away from the nearest water body. There are not any surface hydrologic connections to any waters of the U.S., these wetlands are not located in a geomorphic position that is inseparably bound to any water of the U.S. nor is there any known biological species in this geo-region that requires both the wetland in review and the nearest TNW to full life cycle requirements.

Attached is the aerial photo & USGS map indicated the approximate location of each of these wetlands plus the required JD form and table for the appx. center and size for each wetland polygon.

In conclusion, the Corps has verified that the majority of the site is uplands and there are some pockets of depressional seasonal wetlands on the tract by using on-site and off-site information per the appropriate manual. The wetlands are located in an "isolated" (as defined by federal regulation: 33 CFR 330.2 Definitions:(e) Isolated waters means those non-tidal waters of the U.S. that are:(1) Not part of a surface tributary system to interstate or navigable waters of the US; and (2) Not adjacent to such tributary waterbodies). There is no known nexus to interstate commerce associated with any of them. As such, it is the Corps draft determination that these wetlands would not be subject to federal jurisdiction under Section 404 of the Clean Water Act. Noting as of the date of this e-mail much of this appx. 370 acre site has been impacted & filled and it is the Corps draft determination that these are non-jurisdictional wetlands and as such a non-permitted violation of Section 404 of the Clean water Act does not exist.

Kenny Jaynes
SWG POC

Teague, Kenneth

From: Teague, Kenneth
Sent: Monday, October 20, 2014 1:28 PM
To: Kwok, Rose
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Thanks Rose.

-----Original Message-----
From: Kwok, Rose
Sent: Monday, October 20, 2014 1:28 PM
To: Teague, Kenneth
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

-----Original Message-----
From: Teague, Kenneth
Sent: Monday, October 20, 2014 2:14 PM
To: Kwok, Rose
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Hi Rose- I left you a voice mail about this. We are probably going to elevate this one. Do you have one of Jim Herrington's JD elevation letters? I could use an example. Thanks.

-----Original Message-----
From: Teague, Kenneth
Sent: Thursday, October 09, 2014 2:00 PM
To: Kwok, Rose
Cc: Parrish, Sharon; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

fyi

-----Original Message-----
From: Parrish, Sharon
Sent: Thursday, October 09, 2014 1:58 PM
To: Teague, Kenneth; Kitto, Alison
Subject: FW: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

I think we did address these 51.

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG [mailto:Kenny.Jaynes@usace.army.mil]
Sent: Tuesday, October 07, 2014 12:31 PM
To: Jaynes, Kenneth E (Kenny) SWG; Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: RE: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)

Folks;

Please note there is a typographical error in the last sentence of the 5th paragraph and is should read.........

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Thanks
Kenny Jaynes

-----Original Message-----
From: Jaynes, Kenneth E (Kenny) SWG
Sent: Tuesday, October 07, 2014 12:13 PM
To: Isolated Waters; Parrish, Sharon
Cc: Dixon, Vicki G SWD; Davidson, John SWG; Shivers, Kristin D SWG
Subject: 51 isolated non-jurisdictional wetlands: file SWG-2013-00982; TRENDMAKER - (wetlands 1-51)
Importance: High

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SWG POC